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MONTHLY WEATHER REVIEW

ALFRED J. HENRY, Editor.

VOL. 51, No. 4.
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APRIL, 1923.

CLOSED JUNE 2, 1923.
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THE OCCURRENCE OF LIGHTNING STORMS IN RELATION TO FOREST FIRES IN CALIFORNIA.

By S. B. SHOW and E. I. KOTOK, Forest Examiners.

[U. S. Forest Service, May 10, 1922.]

INTRODUCTION.

Thunderstorms and accompanying lightning are of course known by meteorologists and climatologists as a common phenomenon; the various types are recognized and described, and in Europe, at least, a certain amount of special study has been given them. In western North America, however, their general occurrence in the mountainous areas, far removed from centers of population, and consequently from the principal weather stations, has apparently resulted in rather minor attention to them by professional meteorologists. This is perfectly natural, since especially in California they have but a remote bearing on agriculture, commerce, or navigation, and study of them from any of these standpoints would be of rather academic interest.

The occurrence of these storms is, to be sure, noted by all weather observers of the United States Weather Bureau, and a steadily-accumulating mass of data has long been available, but until relatively recent years no particular reason has existed for careful study of this phenomenon.

Beginning with the creation of the national forests (formerly forest reserves) in California, however, professional foresters, at least, have been forced to a keen realization of the importance of electrical storms, and have been deeply interested in any contribution to our very meager knowledge of their formation, behavior, and action. From the moment that the national forests were put under administration, lightning has proved to be the principal single cause of forest fires in California, and, indeed, throughout the West. Plummer [1] and Palmer [2] have already pointed out the rôle of lightning as a cause of fires, and it is not our purpose to repeat the details of their comprehensive studies. Since the publication of Palmer's paper, lightning has continued to be a major cause of fires in California, varying in intensity from year to year, but never entirely absent. In the decade from 1911–1920, inclusive, in the national forests of California, excluding those in southern California, lightning has been responsible for 4,363 out of a total of 10,527 fires, or 41.5 per cent. The other fires are the result of six causes (grouped as man-caused), and the most important of these is that of camper and smoker fires, numbering 2,239, or 21.3 per cent of the total.

During the decade just passed, a considerable mass of data concerning lightning fires has been collected by the United States Forest Service, merely by the reports on the individual fires from that cause. Since an analysis of these data will throw some light on an obscure subject, this paper is prepared in the hope that it may serve that purpose. It is proposed to treat, first, of the seasonal distribution of lightning fires; second, to analyze the special features from the standpoint of forest-fire protection, especially the characteristic bunching; third, to discuss and define the zones in which they occur; fourth, to study and plot the occurrence of some of the great individual storms of the past 10 years, and lastly to recapitulate the characteristics as affecting fire protection and to point out the special phases of study which appear of most importance and most worthy of attention.

Part of the material presented is unquestionably of less interest to meteorologists than to foresters, but is needed to form a connected story.

Foresters have a special and, perhaps, selfish interest in electrical storms, in that they are concerned with them only as they result in forest fires. So far as they care, lightning may play around the bare granite ridges of the high Sierra every day of the fire season, so long as the storms do not move down into the timber belt of lower altitudes. Lightning zones to them mean areas in which fires are set which spread and must be fought. The season of lightning danger is that in which the forest is dry enough to ignite.

SEASONAL DISTRIBUTION.

Whatever may be the seasonal distribution of lightning storms, lightning fires in California occur in a very concentrated form. This is well illustrated in Table 1, which shows number and per cent of total by months.

TABLE 1.—*Seasonal distribution of lightning fires, 1911–1920.*

Month.	May.	June.	July.	August.	September.	October.	Total.
Total number	109	498	1,436	1,939	331	50	4,363
Per cent of total number	2.5	11.4	32.8	44.3	7.6	1.4	100.0

The months of June, July, and August have 3,873, or 89 per cent of total, while July and August alone have 3,375, or 77 per cent. From the standpoint of fire protection the summer months are by far of the most importance. (See fig. 1.)

Figure 2 illustrates the seasonal distribution of lightning fires so far recorded. Due to the fact that only 10 years' records are available, the curve is not entirely regular, and it has therefore been smoothed to show the probable correct position. The rise to a peak and the equally sudden fall suggest a correlation with temperature changes; the second curve on the figure, therefore, represents the average mean monthly maxima for 39

[1] Plummer, Fred Gordon: Lightning in relation to forest fires. *Forest Service Bulletin* 111, 1912.
[2] Palmer, Andrew H.: Lightning and Forest Fires in California. MO. WEATHER REV., March, 1917, 99–102.

mountain and foothill stations in California having records of 10 years or more. At once it is evident that a reasonably close parallelism exists between the two, with a decided tendency for the fire curve to lag behind that for maximum temperatures. This lag is between a quarter and a half a month. Of course the occurrence of rain and the previous moisture condition of the forest floor affects the starting of lightning fires, particularly in June and September, but the conclusion seems fair that the number of lightning fires will increase as temperatures increase, and will decrease with temperature as well.

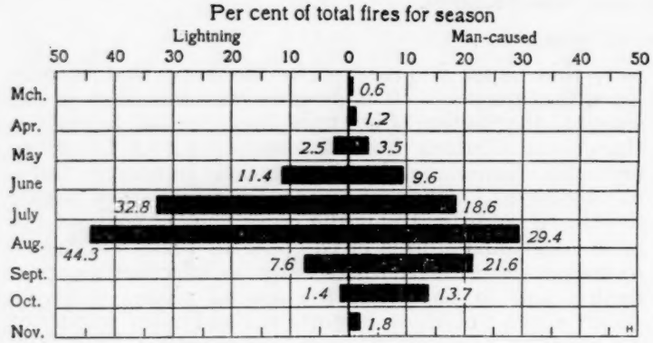


FIG. 1.—Relative percentage of lightning-caused and man-caused forest fires.

INTENSITY OF STORMS.

With the 10 years' data as a basis, a study has been made of individual storms from the standpoint of number of fires set per storm. The data are shown in Table 2.

TABLE 2.—*Summary of individual storms.*

Number of fires per storm.	Number of storms.	Total number of fires.	Per cent "C" fires (over 10 acres).	Size of average fire acres.	Per cent of total lightning fires.	Per cent of total fires per storm.
						Less than—
1–50	(1)	1,687	11.9	49	38.6	0.25
51–150	13	1,164	10.1	29	26.7	2.05
151–250	3	627	11.3	34	14.4	4.80
251–350	3	885	26.5	312	20.3	6.77
Total		4,363			100.0	
Average			14.3	95		

[1] Unknown.

An examination of the data shows that the great majority of storms result in less than 50 fires and are known to be rather local in scope. Storms of the greatest intensity so far experienced—from 251 to 350 fires—have occurred only three times in 10 years. However, study of the table shows that these extraordinary storms are the most disastrous to organized fire protection. Up to the point of 250 fires per storm class "C" fires (those over 10 acres) are held to a low per cent of the total number, and the size of the average fire is fairly low and shows no tendency to increase. But with the heavy storms, fires are so numerous that the existing protection forces are unable to handle all, and some cover large areas, as reflected in per cent of C's and size of average fire. Damage caused by fires varies as acreage burned, and cost of suppression naturally increases as size of average fire becomes greater.

A pressing need of foresters is the short period prediction of these heavy-lightning storms, so that the organization of suppression forces may be completed before, instead of after, the fires start. The extreme intensity of lightning as affecting forest fires is well illustrated in Table 3, which shows for each of the years of the record the per cent of total number of fires due to the single heaviest storm.

TABLE 3.—*Intensity of lightning by years.*

Year.	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	Average.
Number of fires worst storm	116	89	214	108	94	233	339	255	70	295	181
Total fires for year	246	204	691	413	295	388	794	529	181	621	436
Per cent of total in one storm	47	43	31	26	32	60	43	48	39	48	42

On the average, 42 per cent of an entire season's fires are caused by one storm, with a range for different years of 26 to 60 per cent. It needs little effort to picture the difficulty, with a limited number of men, of handling business in such concentrated form.

LIGHTNING ZONES.

It is, as has been pointed out, essential for foresters to know where lightning fires are likely to start, so that detection service may be organized to cover such areas, men may be placed in or near them, and other control measures taken. Experience in protection by the Forest Service shows that even within the timber belt, not all areas are subject to lightning fires. In order to determine to what extent the idea of lightning zones is a reality, the starting point of each of the 4,363 lightning fires was plotted on a State map. At once it was evident that zones did exist and lines were drawn outlining these. Figure 3, which is reduced from the original map thus made, shows for the State of California the lightning fire zones in and adjacent to the national forests. For obvious reasons it is impossible to show each individual fire, but the intensity within the zone is indicated by broad classes, giving number of fires per township of lightning zone. Four intensities are recognized within the general lightning zone:

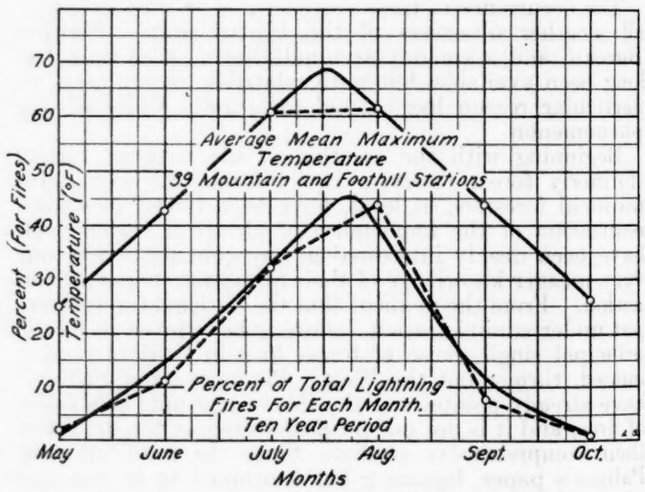


FIG. 2.—Relation between percentage of forest fires started by lightning and the average mean maximum temperature.

1. Less than 5 fires per township, classed as light intensity.

2. From 6 to 10 fires per township, classed as medium.

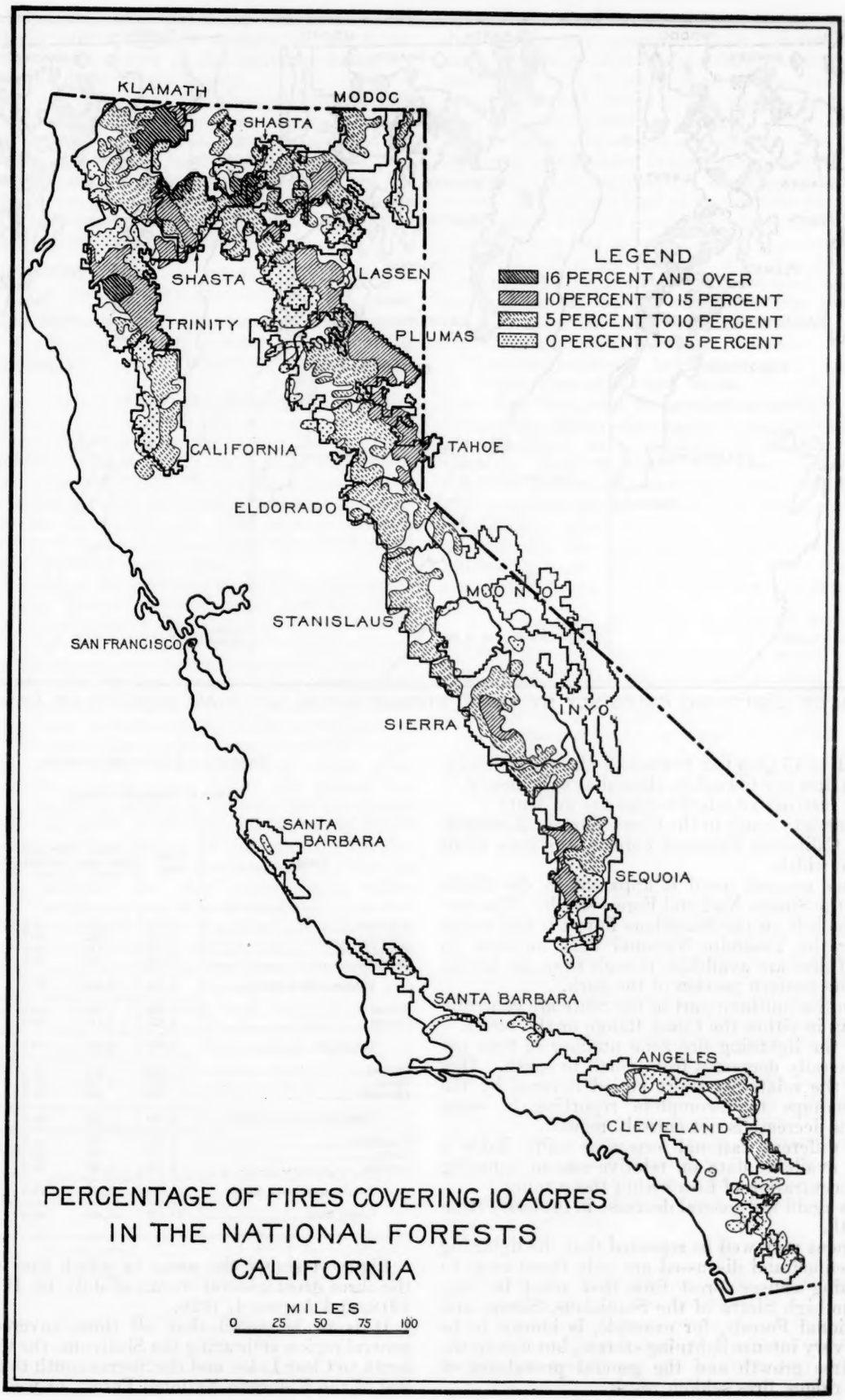
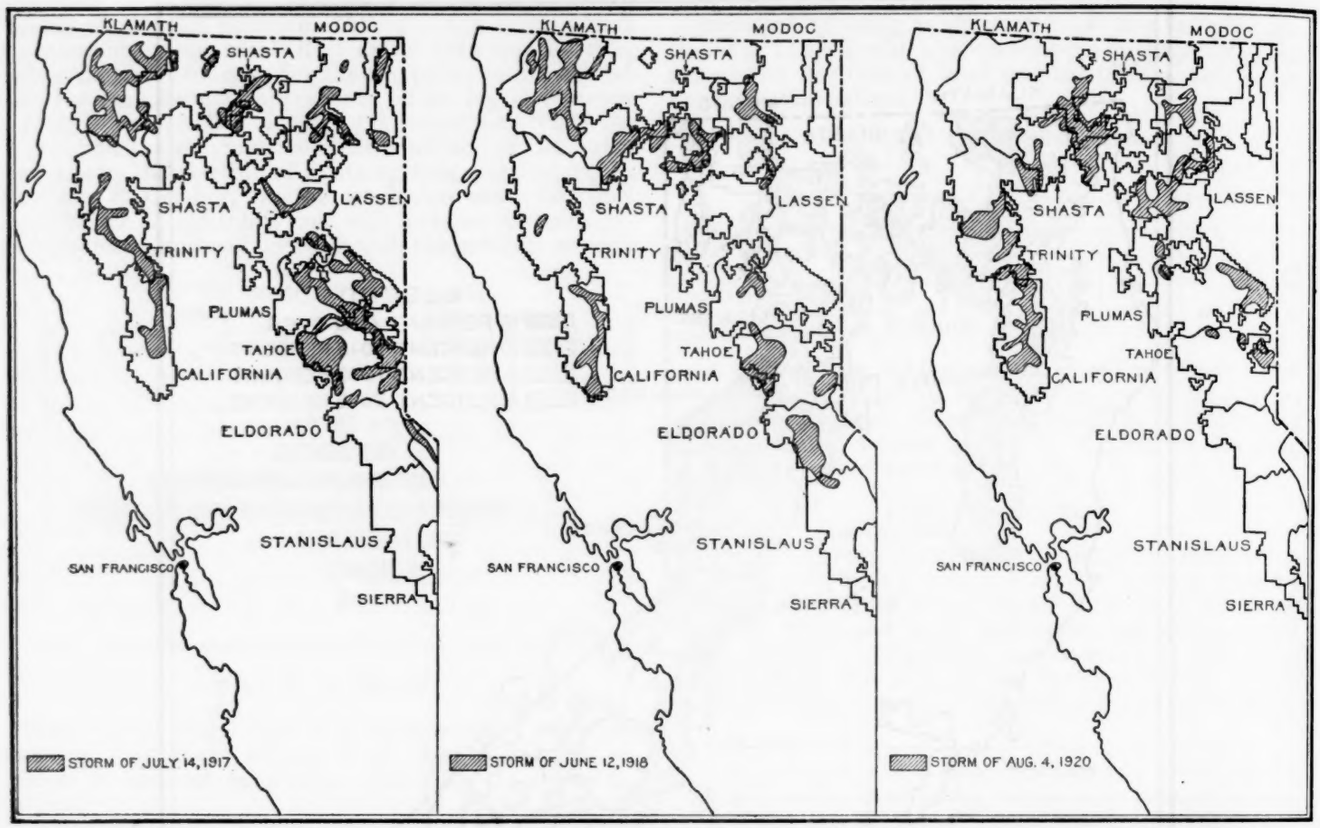

KLAMATH
MODOC
SHASTA
SHASTA
LASSEN
TRINITY
PLUMAS
CALIFORNIA
TAHOE
ELDORADO
MONO
STANISLAUS
SAN FRANCISCO
INYO
SIERRA
SANTA BARBARA
SEQUOIA
SANTA BARBARA
ANGELES
CLEVELAND
LEGEND
16 PERCENT AND OVER
10 PERCENT TO 15 PERCENT
5 PERCENT TO 10 PERCENT
0 PERCENT TO 5 PERCENT
PERCENTAGE OF FIRES COVERING 10 ACRES
IN THE NATIONAL FORESTS
CALIFORNIA
MILES
0 25 50 75 100

FIG. 3.



LOCATION OF LIGHTNING FIRES SET BY THREE STORMS IN THE NATIONAL FORESTS OF CALIFORNIA

FIG. 4.

3. From 11 to 15 fires per township, classed as heavy.
4. Over 15 fires per township, classed as very heavy.

Some very instructive relationships are evident:

1. From north to south in the Coast Ranges (Klamath, Trinity, and California National Forests) the zone tends to decrease in width.

2. The same general trend is apparent in the Sierra region, from the Shasta National Forest south. The narrowness of the belt on the Stanislaus Forest is due to the fact that for the Yosemite National Park no data on occurrence of fires are available, though they are known to occur in the western portion of the park.

3. Zones in the southern part of the State are generally narrower than in either the Coast Range or the Sierra.

4. Within the lightning fire zone number of fires per township generally decreases from north to south. Due probably to the relatively short period covered by the data and perhaps to incomplete reporting in some instances, this decrease is not entirely regular.

Using the different national forests as units, Table 4 presents the available data on relative size of lightning zone and concentration of fires within those zones.

This shows again the general decrease in intensity from north to south.

The statement may well be repeated that the lightning zones here defined and discussed are only those areas in which lightning causes forest fires that must be suppressed. The high Sierra of the Stanislaus, Sierra, and Sequoia National Forests, for example, is known to be subjected to very intense lightning storms, but due to the scarcity of tree growth and the general prevalence of high granite ridges, fires seldom result.

TABLE 4.—*Lightning zone areas.*

[Areas in thousands of acres.]

Forest.	Total area.	Area lightning zone.	Per cent of total area.	Total fires, 10 years.	Fires per 100,000 acres of lightning zone area.
Klamath	1,744	1,110	63.7	684	61.5
Trinity	1,746	1,042	59.7	499	47.9
Shasta	1,587	1,145	72.2	558	48.8
California	1,063	749	70.5	165	22.1
Total northern group	6,140	4,046	65.8	1,906	47.2
Modoc	1,583	895	56.5	334	37.2
Lassen	1,321	1,118	84.5	389	34.8
Total east side group	2,904	2,013	69.6	723	35.9
Plumas	1,433	922	64.3	484	52.4
Tahoe	1,271	1,032	81.3	312	30.2
Eldorado	836	425	50.8	189	44.5
Total north Sierra group	3,540	2,379	69.8	985	39.7
Stanislaus	1,104	628	56.8	164	26.1
Sierra	1,663	674	40.5	250	37.1
Sequoia	2,022	1,090	53.9	335	30.7
Total south Sierra group	4,789	2,392	49.9	749	31.3
Grand total	17,373	10,830	63.0	4,363	40.2

Figure 4 shows the areas in which fires were set by the three great general storms of July 16, 1917, June 12, 1918, and August 4, 1920.

It is to be noted that all three covered the same general region embracing the Siskiyous, the Coast Ranges south to Clear Lake, and the Sierras south to the southern end of the Eldorado National Forest, or well over half of

the entire national forest region of California. The August 4, 1920, storm did not apparently affect the extreme northwestern corner of the lightning zone, but elsewhere paralleled the others closely.

It is perfectly evident that the three storms did not cause fires in exactly the same spots, but their spheres of influence were similar enough so that future general storms of a like nature may be expected to repeat past history. Remembering the severe test to organized fire protection that these great storms represent, there can be little necessity to emphasize the need for short period prediction of such potential catastrophes.

CHARACTERISTICS OF LIGHTNING STORMS AND FIRES AS AFFECTING FOREST FIRE PROTECTION.

The previous discussion has pointed out certain features of lightning as affecting forest-fire protection. From the standpoint of the forester, the characters of most importance are:

1. The concentration of lightning fires both in time and place. Such fires occur in well-defined zones, and tend to occur in large numbers on single days. The tendency to bunching in location is a feature making for ease of control by suppression forces, since by a study of zone maps it is possible to locate fire guards in or near the areas on which fires are to be expected. The average distance to travel to fires is thus less than if they were distributed over the entire national forest area.

On the other hand, the tendency to occur in large numbers at one time makes for difficulty of control. Very frequently it happens that a single fire guard must handle several fires in one day, with consequently a high chance of some fires becoming large before suppression work can be commenced. The Forest Service under such conditions uses "emergency guards," i. e., responsible local stockmen, ranchers, miners, etc., hired for a few days to supplement the regular force who are employed for longer periods. Since, obviously, some time must elapse after the occurrence of a heavy storm before this second line of defense can be put in action, it follows that prediction of such storms for even a few hours in advance would materially speed up the attack on the resulting fires.

2. Most lightning storms are accompanied by rain in greater or less amount, the "dry" storm being rather uncommon. This characteristic is of importance in two respects. First, due to the rain, the litter and duff of the forest floor is normally damp, and lightning fires spread more slowly at the start than do fires from other causes. This, of course, makes for ease of control. Second, due to the same fact, many lightning fires, especially those set in standing snags (or dead trees), are unable to spread until the litter has dried out. Such fires, commonly termed "holdover," are often not discovered for several days after the storm. This feature is well shown in Table 5, which gives the per cent of lightning and man caused fires discovered within different lengths of elapsed time after their start.

TABLE 5.—*Relative speed of discovery of and travel to lightning and man caused fires, 1921.*

DISCOVERY.			TRAVEL.		
Length of time after start.	Per cent of total.		Length of time after start.	Per cent of total.	
	Lightning.	Man caused.		Lightning.	Man caused.
0 to 15 minutes	13	36	0 to 15 minutes	9	30
15 to 30 minutes	5	14	15 to 30 minutes	11	17
30 minutes to 1 hour	6	11	30 minutes to 1 hour	14	21
1 to 6 hours	8	15	1 to 4 hours	45	25
6 to 24 hours	35	10	4 to 24 hours	21	7
Over 24 hours	33	4			
Total	100	100	Total	100	100

It is seen that on the average man caused fires are discovered more promptly than lightning; i. e., they start spreading sooner after they are set. Within one hour after start 61 per cent of all man caused fires have been discovered, while in the same period only 24 per cent of lightning fires are found.

The table also shows the relative inaccessibility of lightning as compared to man caused fires as indicated by length of time required for suppression forces to reach them. Within one hour of travel time 68 per cent of all man caused fires are reached, while in the same length of elapsed time but 34 per cent of lightning fires can be attacked. This difference is, of course, due to the well-known fact that man caused fires tend to occur along main routes of travel, while lightning fires characteristically occur on high and inaccessible ridges, where travel must be on horseback or on foot.

This characteristic holding over of lightning fires, of course, works in two ways. It often reduces the peak load that must be handled immediately following a storm, but, on the other hand, there is always an element of uncertainty as to whether or not the crop of fires resulting from a storm has been cleaned up. The holdover fires often break out at unexpected times after the forest has again dried out, and spread rapidly, making for difficulty of control.

Evidently the lightning fires go a longer time unattended than do man caused, and from the fire-control standpoint this is a fairly constant characteristic.

NEEDED STUDY OF LIGHTNING STORMS.

From this sketch of lightning as a major cause of forest fires, it seems evident that study along the following general lines is needed and offers promise of important contributions to our imperfect knowledge of the subject:

1. Formation and movement of individual storms to determine the centers of formation that are believed to exist, the paths followed, etc. Such a study should aid in short period prediction of occurrence of storms in specific localities. The results will be of particular value in connection with the great general storms, which may affect almost an entire State, or perhaps even more than one State.

2. The relation of general weather conditions to the occurrence of storms, especially the general storms. A correlative study of selected heavy storms of the past decade in relation to the weather maps preceding and during these storms appears to be distinctly worth while. From the standpoint of forest-fire control, the prediction of impending storms is of immense importance and the line of investigation suggested should not be neglected.

The study suggested in (1) above has already been undertaken by the Forest Service in California, in 1921, using the men on lookout points as observers. These men, located during the fire season on commanding points, have a unique opportunity to record data on lightning storms. The preliminary work suggests strongly that such data will be of high value. In 1922 it is planned to continue the study.

SUMMARY.

This study of lightning as an important factor in forest-fire control indicates that—

1. The seasonal distribution of lightning fires is highly concentrated, 77 per cent of the total occurring in July and August and 89 per cent in June, July, and August.

2. The seasonal distribution follows closely the course of mean maximum temperatures from month to month.

3. The number of fires set per storm ranges from a few up to nearly 350.

4. Well-defined zones of lightning fires are found to exist in the national forests. Both the relative area of the lightning zone compared to total national forest area, and intensity of fires within that zone are found to decrease, though by no means regularly, from north to south.

5. In general, the regions affected by the three very heavy storms of the past decade correspond.

6. Lightning fires have certain characteristics differentiating them from man caused fires, chief of which are bunching, slow spread at start, and inaccessibility. These affect methods of forest-fire control.

7. An investigation of this important phenomenon is now under way, and further study is needed.

DISCUSSION OF THUNDERSTORMS AND FOREST FIRES IN CALIFORNIA.

By E. A. BEALS, District Forecaster.

[Weather Bureau Office, San Francisco, Calif., April 13, 1923.]

Unfortunately the Weather Bureau has no regular stations reporting by telegraph in the forested areas of California. There are a number of cooperative stations in these regions, but the data obtained from them are very meager. No continuous records of pressure, temperature, humidity, evaporation, wind direction and force have been kept in the forests of California, except possibly sporadically at a few places by the United States Forest Service. Also there are no records of cloud characteristics and their movements. It is quite necessary in order to predict weather phenomena that the forecasters should have available as much information as possible about the weather that is liable to occur in the region for which he makes predictions. This is all the more necessary when the prediction is for a limited area, and for a rather slight change in one or two elements. The foresters want forecasts of drying north winds, of high temperature, and of local or heat thunderstorms. Information regarding these phenomena are wanted as far in advance as possible so they can strengthen their fire-fighting forces, and place them in advantageous positions to combat the fires which they know at such times occur most frequently.

Forests are mostly in mountainous regions, and the surface winds do not always obey the barometric gradients in such localities. The winds blow up and down the canyons, in whatever direction they happen to lie, unless of extraordinary force, when they follow more closely the barometric gradients. To cause the spread of a forest fire the winds need not be very strong; an increase from light (8 to 13 miles an hour) to moderate (18 to 23 miles an hour) is ample to produce a great conflagration. After the fire once gets a good start, it causes inblowing winds that sometimes reach hurricane force without the barometer at outlying stations giving any indication that winds of such force are blowing in that neighborhood.

As to information regarding high temperatures, these phenomena in California generally are of slow growth. The temperature rises from 4° to 6° daily until the thermometer in the valleys reaches about 100°, when it fluctuates to the extent of two or three degrees up or down, until an offshoot from an Arizona LOW moves northeastward. This causes a sudden drop in temperature that lasts for two or three days, when the temperature again begins to slowly rise as before. It is not difficult to predict these hot spells; but we are not always certain as to their duration. One may start without going very far before the break occurs, and that is the great difficulty in predicting them, for, to meet the requirements, it really means a long-range prediction of several days.

Regarding local thunderstorms, weather maps are presented (fig. 1) showing the conditions the evenings before, and on the mornings of the dates when forest fires due to lightning were unusually numerous in California. It will be noticed that there is a great similarity in the weather maps for the different years. In each a trough-shaped low-pressure area extends from Arizona northwestward through California, and on July 16, 1917, and on August 4, 1920, there is a small high-pressure area over Nevada. All the charts show a HIGH impinging on the North Pacific coast.

This type of weather map is frequently in evidence during midsummer, and the difficulty in predicting thunderstorms is that so far as known they occur with this type in just about 50 per cent of cases.

Table 1 shows the temperature for seven days preceding the day when forest fires due to lightning were most troublesome, on that day, and for the two following days. These temperatures of course were taken at stations at the bottom of the valleys in California, and on the plateau on the east side of the Sierra Nevada Mountains. None is representative of the temperatures that actually occurred in the forested areas. They show in a general way a gradual increase in temperature up to the day when lightning fires were most numerous, with a change to cooler either on the days when the fires were most numerous or a day or two later.

TABLE 1.—*Maximum temperatures.*

[Dates of numerous fires due to lightning are inclosed between heavy rules.]

Stations.	July, 1917.									
	9	10	11	12	13	14	15	16	17	18
Red Bluff	98	102	110	110	106	98	110	100	102	100
Sacramento	92	102	106	100	98	94	98	92	96	96
Fresno	98	104	106	106	108	106	106	106	106	100
Reno	88	94	[1] 102	100	102	96	96	88	92	92
Tonopah	90	92	94	[1] 96	94	94	92	88	90	90
	June, 1918.									
	5	6	7	8	9	10	11	12	13	14
Red Bluff	94	96	100	100	102	104	110	92	96	96
Sacramento	92	90	90	98	100	102	108	96	90	88
Fresno	98	94	92	100	106	102	104	104	100	90
Reno	88	88	90	92	90	96	94	94	88	86
Tonopah	82	82	84	84	88	90	92	92	92	90
	July and August, 1920.									
	28	29	30	31	1	2	3	4	5	6
Red Bluff	96	96	96	102	100	100	100	96	96	104
Sacramento	88	92	94	100	98	94	94	90	92	100
Fresno	100	98	98	102	104	102	102	102	96	100
Reno	90	88	92	92	96	92	92	88	90	94
Tonopah	90	90	90	92	90	88	80	82	86	88

[1] Absolute highest.

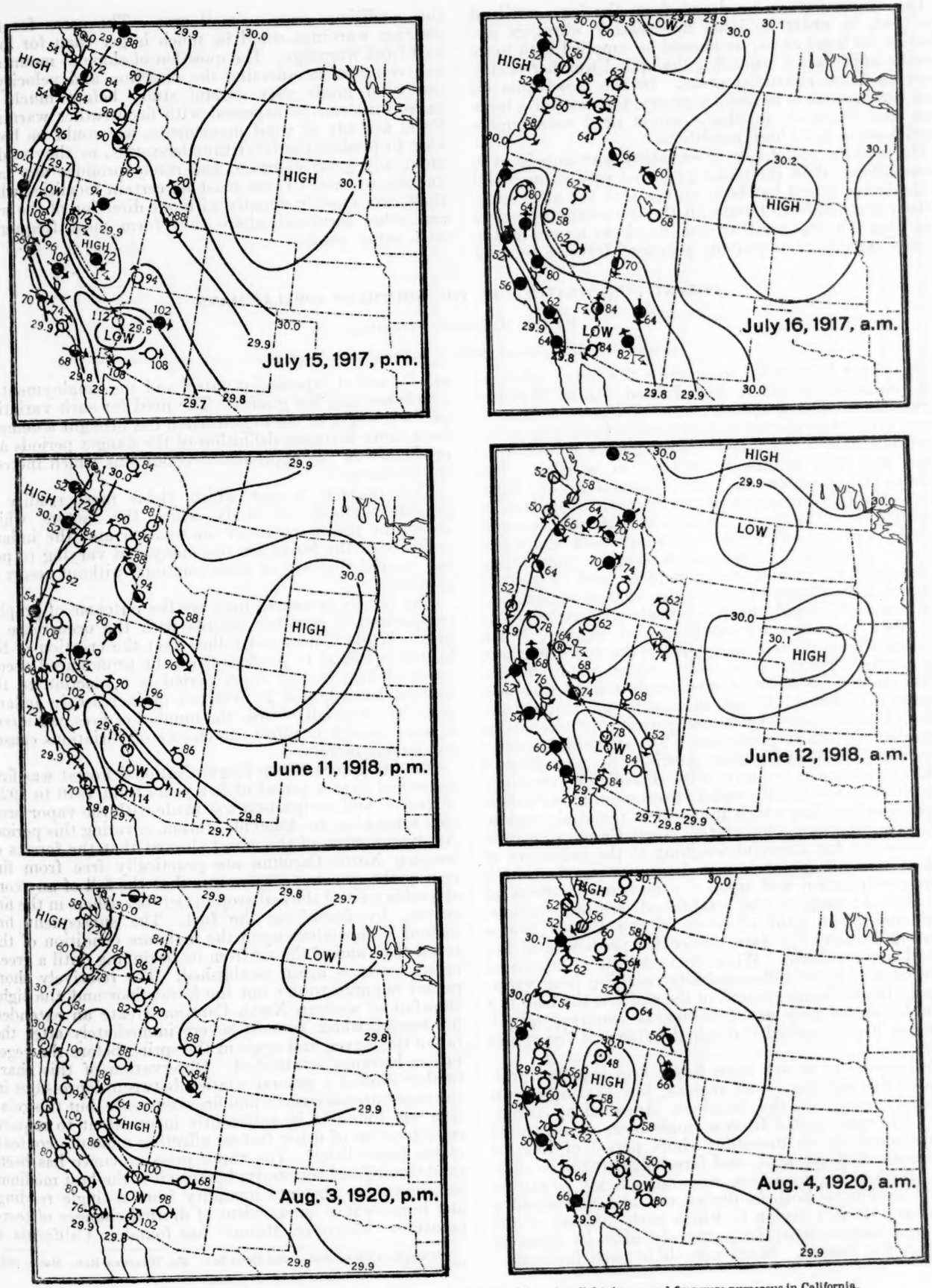


FIG. 1.—Weather conditions on the evening before and the morning of three dates when lightning-caused fires were numerous in California.

The conclusions to be drawn from the facts outlined are that, in order to issue fire-weather warnings applicable for local areas, we should be supplied with more specific information regarding the actual weather taking place in these restricted areas. In the meanwhile all that can be done is to make a general forecast for a large area that probably in places would need considerable amplification to fit local conditions.

The making of reliable fire-weather warnings is even more difficult than the making of frost predictions; and in the latter case it has been proven that the most satisfactory method is to obtain all the information possible regarding the past weather and then have a man on the ground capable of amplifying a general forecast to meet the conditions over a small area. The areas for fire-weather warnings could be much larger than for localized frost warnings. The question of slope of mountains and canyons, as affecting the direction and velocity of the wind needs very careful study before much improvement can be expected with fire-weather warnings. From a study of wind movements, we would be better able to predict the local thunderstorms, as they seldom move any great distance, and rarely produce any large amount of rain. There must be certain localities where they form most frequently with one direction of the wind and other localities where they form most frequently with other winds.

FOREST FIRE WEATHER IN THE SOUTHERN APPALACHIANS.

By E. F. McCARTHY, Silviculturist.

[Appalachian Forest Experiment Station, U. S. Forest Service, May 9, 1923.]

This paper is intended to promote the use of information, collected daily by the United States Weather Bureau, in predicting the occurrence of forest-fire hazard. Forest fires, while started mainly through human agencies, can occur only when forest conditions are favorable to them, and this is directly related to weather. The autumn fall of hardwood leaves, followed by dry days, creates the fall fire season of the Southern Appalachian forest region. The spring fire season is the direct result of dryness of the forest floor following winds and warm dry days of spring. As the season advances the starting of foliage and ground cover reduces and eventually terminates the danger of fire for the summer season.

Although this study has been made with reference to the forest and weather conditions of western North Carolina, the results may be applied to the entire Southern Appalachian region with only minor modifications. While the interpretation of weather data must take into account the local conditions, the storm path through the eastern United States, by its comparative definiteness, is favorable to such prediction. The general easterly movement of storms makes possible the recording of their approach and intensity with considerable certainty because they are usually under observation for two days or more before they reach the eastern mountain region.

The records studied for western North Carolina indicate the necessity for a careful weighing of the influences of each storm as it approaches, to determine its effect, both upon precipitation and upon the moisture content of the air. At each of the established weather stations, conducted by a paid observer of the United States Weather Bureau, the data needed for prediction of fire hazard are available. While there is but a superficial knowledge of forest inflammability resulting from variations in the moisture content of the air, and the field is a suitable one for more exact studies, an empirical knowledge has been acquired through the frequent recurrence of fires.

Promptness of attack upon forest fires is a first principle of fire fighting in all regions, but the urgency is especially great in the Southern Appalachian forest, where fire may spread from a single blaze to a flaming mountainside in an incredibly short period of time, if conditions of slope, wind, and forest floor favor it. The fuel, which is largely leaves, responds quickly to atmospheric conditions both in drying out and in absorbing moisture. It is a region in which each member of the fire organization must be extremely alert in times of greatest fire hazard. Short periods in each fire season call for added expense for patrol and the employment of supplementary fire guards. The need for such variation in the strength of the organization has brought a demand for a more accurate definition of the danger periods and prediction of the approach of conditions which increase the fire hazard.

This problem is one which yields most readily to graphic methods of study, since the factors which determine the character of the weather and the inflammability of the forest are too many and varying to permit mental mastery of their relations without resort to graphs.

The results presented here are the outcome of graphic comparison of weather records with the occurrence of fires. While it does not follow that the creation of fire hazard is bound to produce fires, the pronounced occurrence of fires in any short period is a reaction to the natural hazard, and is evidence of increase in inflammability, especially where the number of fires considered is large enough to offset the chance of variations caused by outside factors.

The fire record of the Pisgah National Forest was first examined over a period of five years from 1916 to 1920, inclusive, and comparison was made with the vapor pressure record for the Asheville station, covering this period. An examination of this chart showed that the forests of western North Carolina are practically free from fire during the growing season, but that the fall of any considerable part of the leaf crop in October ushers in the fire season, by furnishing the fuel. The subsequent fire hazard is dependent upon the moisture condition of the forest floor and of the air from its beginning until a green crown cover is again established. The relatively short period required to dry out the forest floor and the light snowfall of western North Carolina create an extended fire season, which is most severe immediately after the fall of the leaves, and again in the spring before the vegetation becomes established. Observation of this chart further showed a general relation between depressions in the vapor pressure curve and fire occurrence, but this relation was found to be sufficiently inconsistent to require consideration of other factors affecting moisture content of the forest litter. The vapor pressure curve has been used throughout the study, because it is the best medium for expressing absolute humidity from a single reading and because it is independent of diurnal changes of temperature. Moreover, Munns [1] has found in California a

[1] Munns, E. N.: Evaporation and forest fires. MO. WEATHER REV. March, 1921, 49: 149-152.

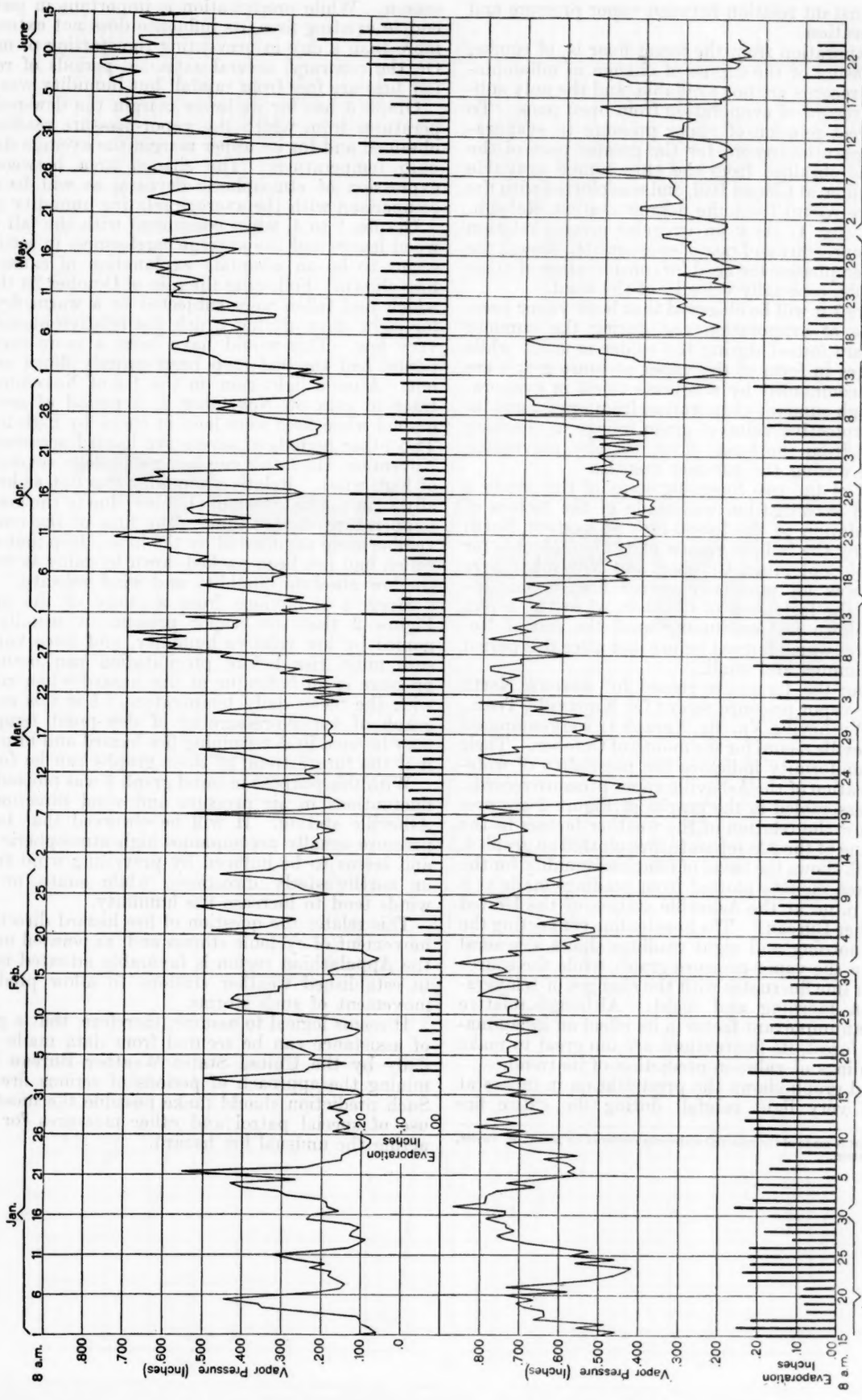


FIG. 1.—Vapor-pressure graph based on 8 a. m. and 8 p. m. reading at Raleigh, N. C., January to November, 1922, with daily evaporation from open pans at Chapel Hill, N. C.

reasonably constant relation between vapor pressure and rate of evaporation.

Rate of evaporation from the forest floor is, of course, the direct measure of the degree of change in inflammability. Such records are not available, and the only substitute is the record of evaporation from open pans. To check the direct relation of vapor pressure to evaporation, the evaporation record for the greater part of the year 1922 was obtained from the only source available in North Carolina, at Chapel Hill, and was plotted with the vapor pressure record from the nearest station, Raleigh. These graphs (fig. 1) show an irregular inverse relation between vapor pressure and rate of evaporation, though the irregularities emphasize the need for consideration of other physical factors, especially velocity of the wind.

From Figure 1 it will be observed that both vapor pressure and rate of evaporation rise during the summer months and are lowest during the colder months, while sudden changes in form of the vapor pressure graph are commonly accompanied by a reverse trend in evaporation. The high summer evaporation from open pans indicates the protective value of green foliage in checking loss of water from the forest floor, thereby preventing a fire hazard during the summer months.

As a result of the two foregoing steps of this study a more detailed investigation was made of the factors of weather in relation to the forest fires of western North Carolina during the fall fire season of 1922. Records for the months of September, October, and November were used. This was an unusually severe fire season, beginning with the last week of October, when the leaves were partly down and continuing until the end of November. Fires which burned before and after this period were few in number and small.

Before using the forest-fire record for western North Carolina, the vapor pressure record for Knoxville, Tenn., and that for Wytheville, Va. (fig. 2, graph 4), were compared with the Asheville record for the month of October. Their remarkable uniformity indicates the possibility of widespread application of the Asheville vapor pressure records.

The data assembled in the graphs of Figure 2 are presented to show the relation of the weather factors to the time of starting of the 228 separate fires plotted on graph 4. The first graph shows the trend of relative humidity for the period of three months plotted from readings made at 8 a. m. and 8 p. m. at the Asheville station of the United States Weather Bureau.[2] The heavier line connecting the average of morning and night readings shows a general conformity to the vapor-pressure graph, while the source of the lighter line fluctuates with the changes of temperature between morning and night. Although relative humidity is an important factor in its effect on inflammability of the forest, its fluctuations are too great to make any two readings of value in prediction of its trend.

The second graph shows the precipitation in inches at Asheville, a very light rainfall during the entire fire season. While precipitation is important in putting an end to existing fires, its influence does not extend much more than a day in preventing the starting of new fires. On the contrary, several extended periods of relatively few fires are free from rainfall but humidity was high.

Graph 3 has for its lower margin the dew-point temperatures from which the vapor-pressure readings were obtained and for its upper margin the average daily dry-bulb temperatures. The shaded area between is an expression of atmospheric dryness, as will be seen by comparison with the average relative humidity graph.

Graphs 1 to 4, when considered with the fall of hardwood leaves and the average carelessness in setting fires, seems to be an adequate explanation of cause for the fires shown. Following the rain of October 23 the leaves which had fallen were subjected to a warm dry period for eight days, during which the relative humidity was very low. This would have been a more serious fire period had the leaf crop been entirely down and dried out. After a light rain on the 1st of November and a trace of rain on November 2, a period of seven days ensued when fires were held in check by high humidity. Two other periods of severe fire hazard occurred during November, the latter one being especially severe because of high wind. Relative humidity was not as low generally as in the last week of October, due to the lower mean temperature at this time. The fires of the end of November were augmented by the loose, deep mat of leaves which had not been packed down by rains as well as by the low absolute humidity and wind velocity.

Since it is obvious from a study of the graphs of Figure 2 that low vapor pressure is usually accompanied by low relative humidity, and since vapor pressure must rise before precipitation can occur, vapor pressure is an indicator of fire hazard when considered with the mean daily temperature. For this reason the graph of vapor-pressure or of dew-point temperatures may be used in determining fire hazard and in predicting it if the future trend of these graphs can be foretold.

With this purpose in mind graph 5 was plotted to show fluctuations in air pressure and wind direction at the Asheville station. It will be observed that low vapor pressure usually accompanies high atmospheric pressure and seems to be induced by prevailing wind from west or northwesterly directions, while south or easterly winds tend to increase the humidity.

This relates the question of fire hazard directly to the movement of cyclonic storms and, as pointed out earlier the Appalachian region is favorably situated in relation to established weather stations to allow prediction of movement of such storms.

It seems logical to assume, therefore, that a great deal of assistance can be secured from data made available daily by the United States Weather Bureau in determining the approach of periods of serious fire hazards. Such prediction should make possible the most efficient use of special patrol and other measures for counteracting the unusual fire hazard.

[2] Acknowledgment is made of the material assistance rendered by Mr. T. R. Taylor, observer at this station.

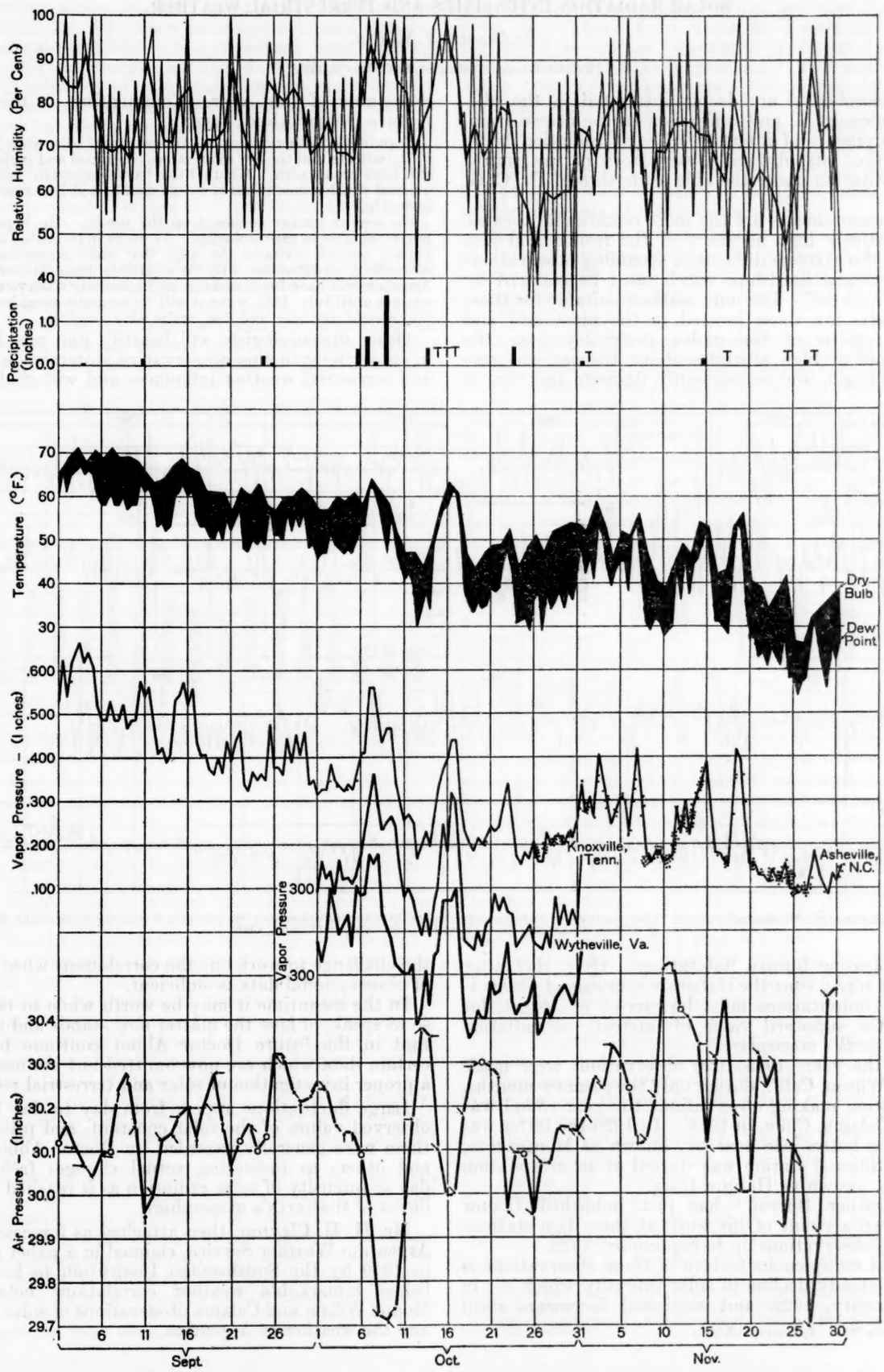


FIG. 2.—Weather records for months of September, October, and November at Asheville, N. C., with plotted record of time of beginning of 228 forest fires in western North Carolina. *Graph 1.* Relative humidity plotted from two readings a day and heavier line showing mean daily average. *Graph 2.* Precipitation. *Graph 3.* Dew-point temperature plotted from two readings a day and mean daily temperature averaged from morning and night dry-bulb readings. *Graph 4.* Vapor-pressure record for Asheville, N. C., Knoxville, Tenn., and Wytheville, Va., with fires shown approximately at the hour of occurrence. *Graph 5.* Record of atmospheric pressure and wind direction from one reading each day.

SOLAR RADIATION INTENSITIES AND TERRESTRIAL WEATHER.

By CHARLES F. MARVIN.

[Weather Bureau, Washington, D. C., May 12, 1923.]

All meteorologists are deeply interested in the ultimate significance of, and conclusions to be drawn from, the measurements of intensity of solar radiation being made by the Astrophysical Observatory of the Smithsonian Institution under the able leadership of Dr. C. G. Abbot.

These measurements are the more remarkable because of the relatively high accuracy of the results and also because of the extreme difficulties attending observations and the personal hardships which must be endured by the observing staff. The only stations suitable for these investigations are those located in the most arid and cloudless regions of the globe, preferably near the Equator and at high altitudes above the sea and surrounding terrain, and consequently desolate and remote from all pleasing human habitations. Here, day after day, under torrid suns the elaborate schedule of observations and computations must be carried on to get, for the day, the supposed value of intensity of radiation *outside the earth's atmosphere*.

During the years 1905–1920 observations were made at Mount Wilson, Calif., during only the summer months. A new station making observations the year round was set up at Calama, Chile, in 1918. In 1920 the latter was moved to a better site near by, known as Montezuma; and an additional station was started at an arid station in Arizona, known as Harqua Hala.

The Weather Bureau [1] has just published Doctor Abbot's own account of his work at these two stations and all the observations up to September, 1922.

The most conspicuous feature of these observations is a seeming steady decline in solar intensity which set in during January, 1922, and continued downward until September of that year. Commenting on this notable feature Doctor Abbot says:

> Unpublished observations at Arizona and Chile since September, 1922, indicate that the low solar values continued and perhaps became still more pronounced. Whether this has an important bearing on the unusual weather conditions of recent months will be for meteorologists to decide.
>
> We reserve further comment on the results. We hope they will prove valuable to meteorologists. As we have intimated already, the present outlook warrants the hope that more numerous and more concordant observations will be available from January 1, 1923. Arrangements have been made to continue daily observations at both stations until July, 1925, when it will be earnestly considered whether they should continue, and if so, under what auspices.

Other meteorologists will heartily join me, I believe, in subscribing to this conservative statement as to solar and terrestrial weather influences and will gladly accept the challenge to work out the correlations when the body of observational data is sufficient.

In the meantime it may be worth while to take stock, so to speak, of how the matter now stands and to request that in the future Doctor Abbot continue to publish certain data which are now omitted but are necessary to a proper investigation of solar and terrestrial relations.

Large fluctuations appear from day to day in all the observed values of the solar constant, and prior to 1920 these were generally regarded by Doctor Abbot himself and others as indicating actual changes from day to day in intensity of solar radiation as it reached the outer limits of the earth's atmosphere.

Mr. H. H. Clayton, then attached as forecaster to the Argentine Weather Service, claimed in a paper published in 1919 by the Smithsonian Institution to have established remarkable weather correlations between the Mount Wilson and Calama observations of solar radiation and the weather of Argentina.

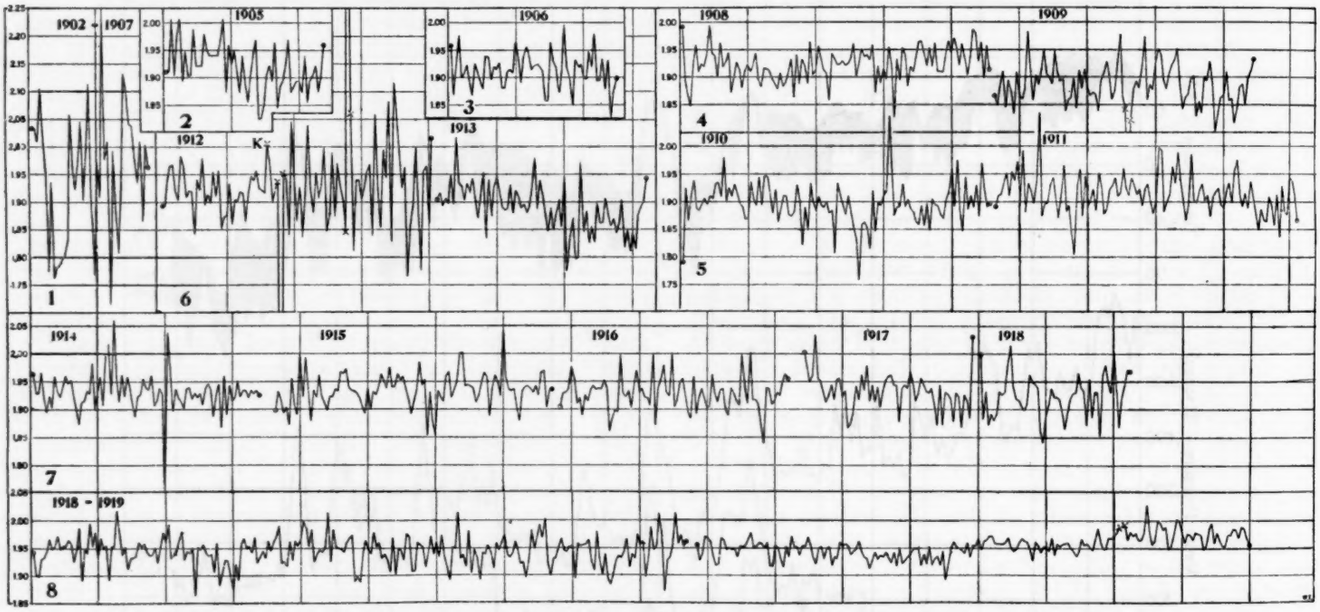


FIG. 1.—Diagram of nearly 2,000 observed values of "solar constant" as determined by the Smithsonian Institution from the beginning of observations in 1902 to the end of 1919 at stations Washington, D. C., Mount Wilson, Calif., and Calama, Chile.

[1] MO. WEATHER REV. February, 1923, p. 71.

The present writer seriously questioned [2] not only the soundness of Mr. Clayton's investigations and conclusions, but gave evidence on a statistical basis tending very strongly to show that the day-to-day apparent changes in intensity of solar radiation are really largely errors of observations due to the turbidity of the earth's atmosphere for which no allowance whatever was made by Mr. Clayton. If there is on the average any appreciable day-to-day change of intensity of radiation reaching the outer atmosphere of the earth it can not be more than a small fraction of 1 per cent, since statistically examined we find the probable day-to-day variation has grown smaller and smaller as improvements have been made in instruments and methods and stations have been better located for making such observations. (See figs. 1 and 2.)

Figure 1 tells a very important story with great force and plainness. Great variations in consecutive values of intensity mark the early observations in Washington

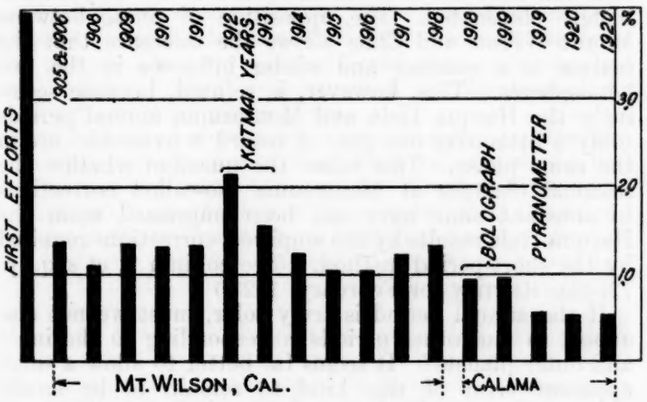


FIG. 2.—Height of bars shows probable error of an observation for a single day of the intensity of solar radiation as measured by the Astrophysical Observatory of the Smithsonian Institution at Washington, D. C., Mount Wilson, Calif., and Calama, Chile.

with imperfect equipment and poor atmospheric conditions.

Observations at Mount Wilson from 1905 to 1912 show far more nearly constant values of radiation until the arrival of the atmospheric dust from the Katmai volcanic eruption, after which day-to-day or consecutive values showed great variations. Everyone probably ascribes these increased variations not to increased solar activity, but to inaccuracies of measurement due to atmospheric dust. The large variations disappeared with the dust. Furthermore, some increased accuracy (smaller variations) characterized the observations at the station at Calama, Chile, either because of the better instrumentation, greater observational experience, or better observing conditions, or all of these in combination.

Finally, it is most striking that a further marked reduction in day-to-day variability immediately resulted from the introduction in 1919 of the pyranometer method of observation.

The percentage *probable error of a single value* has been carefully computed for each group of observations and the results are shown graphically in Figure 2.

Entirely terrestrial causes easily explain the great changes and gradual diminution in variability shown by the observations, the accuracy of which has been wonderfully increased by improvements in instruments, methods, and location of stations. What are now regarded as good observations *for a single day's work* show a probable error as low as five-tenths or six-tenths of 1 per cent. This is remarkable precision. This analysis of the whole body of radiation data brings one face to face with the important question:

Is all of this five-tenths to six-tenths of 1 per cent of day-to-day variation in solar radiation intensities real error of measurement only? Or is part of it error of measurement and part real solar change? If the latter, what are the respective amounts of each variation?

That the writer is not alone in the opinion that the day-to-day changes in observed values of the so-called "solar constant" are best explained by the changing transmission of the earth's atmosphere is shown by the following citations:

> It is not claimed that the solar constant does not vary, but that its variations are marked by changes in the atmospheric transmission, when the observations are made through different air masses.[3]
>
> *Solar Constant.*—Their investigations lead the authors to believe that strong reasons can be raised against the reality of the interdiurnal variation of the solar constant; and that the apparent variations are due to changes in atmospheric turbidity.[4]

From the evidence now available the writer holds to the conclusion that the day-to-day up-and-down fluctuations of observed intensity of solar radiation are largely due to the uncorrected effect of atmospheric transmission, and if there is any real day-to-day fluctuation of actual intensity of radiation it must be but a small part of the apparent fluctuation.

Slow progressive and long-time changes in solar constant.—Doctor Abbot's paper in the February REVIEW places emphasis upon the striking decline in solar constant values throughout the year 1922. It would be decidedly premature to venture any opinion whatsoever concerning such a feature of the observations or its influence on the present or future weather conditions. It is well known the sun is approaching a state of minimum spottedness, and Doctor Abbot's solar observations are of very great interest and importance. Obviously, we must patiently await the complete passage of the minimum and at least the partial return toward the next maximum of spottedness. Doctor Abbot assures the continuance of his present stations until July, 1925, which at best may be only slightly beyond the present sunspot minimum. It is difficult to overemphasize the unusual importance of the solar observations at this particular period of time.

The values for the next five years or more constitute the climax to the long series which have gone before and promise to furnish data which may help to a better understanding of both sunspot phenomena and the influence of slow progressive changes in radiation intensities on the weather.

Suggestions and requests.—Recognizing the extreme importance of the observations now in progress at the two observatories and the fact that the fundamental Langley or so-called complete long method is employed only infrequently, we venture to express the hope that the entire homogeneity of the ultimate body of data be preserved by *making and publishing the greatest practicable number of measurements by the long method at both stations*. Those for Harqua Hala are omitted entirely from the data in the MONTHLY WEATHER REVIEW for

[2] MO. WEATHER REV., March, 1920, p. 149.

[3] H. Knox-Shaw: Observations of Solar Radiation, 1915-1921. *Bulletin No. 23, Helwan Observatory, Ministry of Public Works, Egypt, Physical Dept.*, p. 256.

[4] *Science Abstracts, Physics.* F. Linke and K. Boda. *Meteorologische Zeitschrift.* 39, June, 1922, pp. 161-166.

February. Of these Doctor Abbot says (p. 74, second column):

> We have made no use of "long-method²" values at Harqua Hala, except for determining "function transmission curves." We consider them individually so much less accurate than "short-method¹" values, because they are influenced by clearing up or hazing up of the atmosphere, while short-method values are not, that to include them in the mean values would injure the work. The observers at Montezuma have been accustomed to give "long-method²" values half weight. We have thought it best not to alter their "weighted mean³" values already published in the MONTHLY WEATHER REVIEW, but have modified the grade assigned.

The seeming discredit cast by Doctor Abbot himself upon these long-method results is a surprise to the writer because that method is fundamental and one whose average values must be more accurate and dependable than those by the empirical or short method. The case is somewhat analogous to adopting aneroid barometers for measurements of air pressure to replace fundamental mercurial standards. It is very difficult to properly appraise the real value of the so-called short method which requires for the *evaluation* of its indications a whole train of complicated "function" values of a highly arbitrary and empirical character. The "short-method values" are acceptable only when they follow closely in step with long-method values under good observing conditions.

The writer recognizes that the so-called short method may possibly give truer indications of short-time fluctuations of apparent solar intensity, but it is difficult to believe that in the long run short-method observations can be of superior accuracy to the long method, which must be relied upon for evaluating the long train of complicated "function" values required in the use of the short method. It is again hoped and urged that frequent long-method observations be made and published for each station. It seems highly important also that the observations at the Arizona and Chile stations be made *absolutely independent of each other*, without the application of coordinating corrections that are designed to bring about some imaginary agreement between these two stations. The Weather Bureau fully recognizes that outstanding constant differences may arise, but it seems premature to attempt to evaluate these differences and apply arbitrary corrections to these observations at this early time in the history of the two stations. That is to say, the writer believes the observations should be made as absolutely independent of each other as possible and all outstanding differences harmonized when a large body of observational material is available for dicsussion. Various corrections have been applied to the records in the past which might perhaps better have been left to be determined and evaluated in a final discussion of the material.

Annual period.—Figure 8 of Doctor Abbot's article in this REVIEW for February shows a well-defined 12-month period with maxima values about January. A tendency toward a similar period but opposite in phase can be shown in the Mount Wilson data. Observations at the latter station, however, especially after 1916, extended over such a short portion of the year that a periodic tendency can not be conclusively evaluated.

The logical inference is that any annual period of this character must be due to changes in atmospheric absorption and that the effect of the latter is not as yet completely eliminated. The opposition of phase between Mount Wilson and Chile allows the inference that the feature is a summer and winter influence in the two hemispheres. This, however, is refuted, because seemingly the Harqua Hala and Montezuma annual periods (only a little over one year of record is available) are in the same phase. This raises the question whether the seasonal changes at Montezuma (so-called corrections to constant sun) have not been impressed upon the Harqua Hala results by the empirical corrections required by the short-period method. (See column 2, et seq., p. 73, this REVIEW for February, 1923.)

If the annual period is truly solar, must we not also expect to find other periods corresponding to the inner and outer planets? It seems far better to allow a small apparent error of this kind to remain to be finally evaluated when the body of data is large enough to permit the error to be most assuredly evaluated by rigorous statistical methods.

Placing the highest valuation on long method observations, it is hoped the results of all such for both Harqua Hala and Montezuma may be included in the observations which are submitted for publication in the MONTHLY WEATHER REVIEW from time to time.

WEATHER FORECASTING FROM SHIPS AT SEA.

ALFRED J. HENRY, Meteorologist.

[Weather Bureau, Washington, D. C., May 23, 1923.]

With the development of radio transmission in the early years of the twentieth century, one of the very first practical applications of the new method of transmission was in the issue of warnings of dangerous storms to vessels at sea.

As early as 1906, therefore, arrangements had been made by the United States Weather Bureau to dispatch weather forecasts and warnings to all vessels within the zone of communication that were equipped with radio apparatus.

At that time the idea of a central floating weather station had not developed, but it was thought that perhaps the accuracy of the forecasts might be improved by extending the field of observations from land to water areas, hence arrangements were made whenever possible to transmit ships' observations to shore stations. As it turned out, the extension and development of radio transmission found its fullest expression in eastern United States and northwestern Europe so that vessels navigating the north Atlantic lanes of travel were first to be in a position to communicate with shore stations. For a short time, ships' observations from the north Atlantic were collected by the United States Weather Bureau, but the collection was suspended in the last half of 1907. In the next year, 1908, the outstanding event was the test of the feasibility of the plan of constructing a weather chart on board ships navigating the high seas. This test became possible through the generosity of the Hamburg-American Line in cooperation with Dr. P. Polis, director of the Aachen Meteorological Observatory.[1]

Doctor Polis made the trip, Cherbourg to New York and return, in 1908. The plan followed was to arrange for the transmission of a few reports from European land stations and to supplement these daily by such ships' reports as could be collected. At that time radio transmission from European stations was not effective beyond about 1,800 miles from the British coast; reports from the eastern portion of the United States were

[1] Polis, P.: Wireless telegraphy in the service of meteorology, MO. WEATHER REV. 36: 407.

then picked up. Although Doctor Polis did not have much material at his disposal a fairly useful map was constructed and the experiment was considered as a success.

The way to an immediate adoption of the plan was not, however, clear; the questions of tolls, codes, and international agreement had first to be disposed of. An International Conference on Radio-Telegraph Transmission was held in Berlin in 1906, a second one in London in 1912, and a third was set for Washington in 1917; for reasons that can easily be recognized the last one was not held, and, moreover, some of the original questions are still under consideration.

In the meantime, it was realized on this side of the Atlantic that the extension of radio transmission of ships' observations made in West Indian waters to the United States Weather Bureau would be productive of useful results; and accordingly, in 1912, a plan of operation whereby meteorological observations were to be made twice daily on ships navigating the Gulf of Mexico, the Caribbean Sea and adjacent waters and transmitted by radio to the United States Weather Bureau was put into effect. The new plan differed from the old in providing for a small compensation for the taking of the observations at stated hours.

In all, about 50 vessels were commissioned to observe twice daily; it was hoped that these reports would be received in the Central Office of the Weather Bureau in Washington in time for use in the preparation of the twice daily forecasts and warnings, a hope that was not always fully realized, although the system proved to be vastly superior to that which was used in the early days of radio transmission.

Prior to 1913, the thought in connection with radio transmission was centered upon the idea of collecting ships' observations for the use of the forecaster at a central land station; in 1913, however, the bureau began to broadcast the meteorological observations taken at a line of coast stations extending from Sydney to Key West.[2] At a later date the original number of land observations broadcast was greatly increased.[3]

The interception of these observations, as well as those made in West Indian waters, of course, made possible the preparation of weather maps and the study thereof immediately on board ship. This was obviously the most effective solution of the problem of keeping the navigator advised as to the meteorological conditions prevailing on the continents and in his immediate vicinity. While this opened up the possibility the problem was only partially solved; what was needed was a forecaster on board the vessel, but the matter received little attention during the actual period of the Great War. Shortly after the war closed the forecasting problem of the Atlantic was actively taken up by the French Weather Bureau (Office National Météorologique) . In a communication from that Bureau under date of April 3, 1922, it was indicated that the object sought could be realized, and in support of this view the experience on board the steamer *Jacques Cartier* was cited, as follows:

> On board the *Jacques Cartier* were received the American bulletin and European meteorological messages broadcast by the Eiffel Tower; moreover, passing ships were asked to give meteorological reports for certain hours. Daily forecasts were made on board in accordance with the methods of the National Meteorological Office (study of the movement of variation centers and of cloud systems). These forecasts which gave the best results were broadcast by radio in French and in English to the ships en route. Besides when the *Jacques Cartier* was in touch with European wireless stations, data were forwarded to France.
>
> Thus on the *Jacques Cartier* was realized a first outline of the Atlantic station of centralization forecasting and broadcasting—unfortunately this was a moving station.
>
> In spite of the short range of her wireless station only allowing inquiries at a distance of 150 miles by daytime, the steamship *Jacques Cartier* succeeded in gathering daily an average of five or six observations for a given hour.

The above refers to the conditions found in the period immediately preceding April, 1922. Let us now look at the experience of Captain Coyecque on the *Jacques Cartier* on the voyage, New Orleans to Le Havre, February, 1923. Through the courtesy of the Compagnie Générale Transatlantique, Supervising Forecaster Edward H. Bowie, of the Weather Bureau, was given the opportunity of witnessing at first hand the operation of the system practiced on board the *Jacques Cartier*. Below is a condensed account of the eastward voyage by Captain Coyecque:

VOYAGE OF FEBRUARY, 1923, NEW ORLEANS TO LE HAVRE.

[1. Radiotelegraphic results.]

"During the entire crossing it was possible to materialize with considerable precision the meteorological situation over the United States and most of the ocean, thanks to the regular and exact receipt of messages from Arlington, and of the Annapolis-Lyon telegram, known as "Angot-Paris." The Weather Bureau recently decided to add to the stations included in this radiotelegram the Azores observations. The latter, sent by cable from Horta to New York, are taken at 7 a. m. (message 3.30 p. m.) and at 6 p. m. (message 3.30 a. m.). They are particularly interesting for following in the eastern part of the ocean the indications of falling pressure, their passage on the meridian of the Azores. They make possible the determination of the seat of variations.

"From the 17th of February on, that is, off the Bermudas (65° W.), we received the European meteorological message of 4 a. m. (distance, 3,300 miles). It was possible during the crossing of three-quarters of the Atlantic to materialize the isobaric situation from the Aleutians to Russia; that is to say, about 180° of longitude and 50° of latitude. Thus the charts giving the general situation were traced every day by 1 a. m., Greenwich mean time.

"Mr. E. H. Bowie, Chief Forecaster of the American Weather Bureau, who had taken passage on board for this crossing, was very much surprised at this result, which is, to be sure, surprising on first view. We believe we may add that this was the first time that it was possible to realize on board a ship crossing the Atlantic such an exact knowledge of the situation of the weather on the larger part of the Northern Hemisphere at an average of 10 hours after the observations.

"The Arlington day message was received up to the 26th of February (longitude 20° W., distance, 2,500 miles); the night message up to the 1st of March (Ushant, 3,000 miles), with the exception of the break on the 28th of February. These results are analogous to those of our voyage out. The atmosphere became very stormy from the 25th of February, making the reading of long-distance messages very difficult.

"The European meteorological message of 10 a. m. was received and used from the 21st of February on; i. e., at longitude 48° W. (2,500 miles). That of 1 p. m. was used some days after, thus making possible by its combination with the Arlington message the tracing of a chart of synoptic observations for Europe, the Atlantic, and the eastern half of the United States.

Receipt and retransmission of observations made on ships.—"Our return trip was characterized by the receipt of a very great number of ships' observations.

[2] Professor McAdie informs me that weather reports from Tatoosh to San Diego on the Pacific coast were broadcast from San Francisco in 1906 or early in 1907.—EDITOR.
[3] cf. Calvert, E. B.: MO. WEATHER REV. 51 : 1-9.

"In the West Atlantic, and particularly between the Bermudas and the Azores, it was possible to trace all the charts with precision, thanks to the complementary information which we received. The mean number of observations received daily was more than 10. For some days, which coincided with the passing of a very strong tempest in the North Atlantic, we received an average of 20 simultaneous observations from ships. The record was reached on the 22d of Feburary at 1 p. m., with 30 simultaneous observations.

"In the East Atlantic, where the radio traffic is very intense, as usual, we received only one rather feeble mean of observations of ships, but thanks to the message received from the Eiffel Tower, and to our communications with the steamers of the line from New York, the tracing of the charts was not less precise. We retransmitted to the Office National Météorologique the observations of the steamship *France;* those of the *Lafayette,* bound to the southwest of Spain toward the Azores, and finally those of the steamship *Paris*, bound for New York. As soon as this ship lost direct contact with Brest, we took charge of the retransmission of the messages. Two appointments were made a day for this purpose, and the observations of the *Paris* were retransmitted to the Office National Météorologique with ours immediately afterwards.

"The Weather Bureau is disposed to maintain this service of retransmission by the "Angot" message; it wishes only when the *Jacques Cartier* is on the sea, to receive our observations, too. These will be added by the Office National Météorologique to the European messages of "Lyon-Annapolis." We are favorable to this idea, which would make the *Jacques Cartier* play a true rôle of "meteorological cruiser" and centralization station. There would also be a chance to authorize us to transmit clearly the positions of the centers of depression, information which would be exchanged between the two meteorological services via Annapolis-Lyon.

CONCLUSION.

"We believe we can affirm that from the point of view of receipt, as well as of transmissions and retransmissions, we have obtained in the course of the voyage of January and February, 1923, results which are incomparably superior to all preceding ones. Mr. Bowie showed great astonishment at the results obtained. He declared to us that he had never had an idea of the precision with which one could follow the evolution of meteorological phenomena and forecast their effects, while crossing the ocean. We believe that from the moment the United States has verified this success officially, the Office National Météorologique will leave no stone unturned to keep up the present organization of the *Jacques Cartier*, which on this voyage exceeded all hopes. We will close by citing the number of meteorological messages which were received by the two operators of the *Jacques Cartier*, and the number of telegrams of information, general or particular, which were sent. The first number is 500 messages received; the second, 140 messages sent. Finally, we will remark that the results obtained are largely due to the regularity of the radio service and the precision with which the messages are received. The two radiotelegraphers are at present giving us incomparable service, and the training of other operators for this work would seriously upset the enterprises by dissipating our energy for an undetermined period of time. We are therefore of the opinion that it is indispensable to grant to these officers a special indemnity in keeping with the services which they render to the Office National Météorologique and to Atlantic meteorology."

The single example of the weather information broadcast by the *Jacques Cartier* here given will convey an excellent idea of the scope of the meteorological activities of that vessel:

BROADCAST—MARCH 20TH—GREENWICH NOON.

Meteo. *Jacques Cartier* to all ships: North Atlantic weather situaiion March 20th, Greenwich noon.—Pressure is high over northwestern Europe 30.36; also from Bermuda to Azores and northward also over American Atlantic States. Trough of low pressure extending from Iceland (29.60) southeastward to Gibralter (29.50). Disturbance of great intensity (29.00) over Newfoundland moving east-northeastward.

Forecasts.—Track, Azores to Gibralter—unsettled weather eastern portion—northerly fresh winds, squally weather and overcast weather western portion. Stop. Tracks, Azores to English Channel—overcast weather and moderate easterly winds eastern portion—fresh or strong northerly winds and squally weather western portion. Stop Azores region—fresh northerly winds moderating to-day and shifting to southeast and south to-morrow—overcast weather becoming fair. Track, Azores to Bermuda—Moderating northerly winds and fair weather between longitudes 30° and 42°. Southerly increasing winds shifting to southwest west of 42; weather becoming overcast and probably rainy.

Advisory for westbound ships over transatlantic tracks west of Ireland to south of Grand Banks: Disturbance of great intensity (29.00) over Newfoundland moving toward Iceland will be attended by strong shifting winds to-day and to-night between longitudes 35° & 55° followed by fresh or strong northerly winds. Winds will shift to-morrow morning between 40° & 50°.

CONCERNING THE ACCURACY OF FREE-AIR PRESSURE MAPS.[1]

By C. LE ROY MEISINGER, Meteorologist.

[Weather Bureau, Washington, D. C., April 1, 1923.]

INTRODUCTION.

The necessity for knowing the accuracy of the charts.—The computation of barometric pressure at free-air levels is a purely mechanical operation after one has constructed the necessary tables; but the verification of the results of such computations is a much more difficult matter, since a rigidly accurate standard of comparison does not exist. It is true that free-air pressures and temperatures are measured by means of kites, and wind velocities by pilot balloons, but these measures are, for one reason or another, frequently not comparable with the results of computation.

Experience has demonstrated that maps depicting the barometric distributions at free-air levels are often considerably at variance with those representing sea-level conditions. If these differences are real, it is reasonable to suppose that they are physically significant, and one may hope to learn by study and experience what the significance is. On the other hand, if they are false, one may be seriously misled in attempting to interpret them. Therefore, if we are to have confidence in these charts, it is imperative that we ascertain, in every possible way, the degree of accuracy that may be expected of them. This is the purpose of the present inquiry.

The maps upon which the inquiry is based.—The maps examined in the preparation of this paper were constructed daily during the months of December, 1922, and January and February, 1923, from postcard reports mailed to the Central Office of the Weather Bureau at Washington, from 29 Weather Bureau stations in the central and eastern United States. Under the authority

[1] Presented before the American Meteorological Society, at Washington, D. C., Apr. 16, 1923.

of Weather Bureau *Circular*, dated November 20, 1922, these stations were supplied with the necessary reduction tables and instructions for reducing barometric pressure to the levels of 3,281 feet (1 kilometer) and 6,562 feet (2 kilometers) above sea-level.[2]

The method by means of which the reduction tables were constructed has been completely set forth in MONTHLY WEATHER REVIEW SUPPLEMENT No. 21,[3] and will not be discussed here.

The postcard reporting was discontinued at the end of February in order that time might be afforded for a complete and careful study of the results. It was believed that if these months—the season of the weather's most annoying caprices—should yield results of value, even brighter should be the prospects during less active seasons.

COMPARISONS OF OBSERVED AND COMPUTED PRESSURES.

The problem of obtaining comparable data.—In seeking to arrive at an estimate of the accuracy of the results of computation, one of the most obvious methods is to compare the computed pressure (based upon surface observations) with that reduced from the record of the kite meteorograph. At first sight, this seems a direct and simple comparison, but, in truth, it is neither direct nor simple; for, between the vibrant pen of the meteorograph, tracing its record among the clouds, and the columns of cold figures whence the residuals are derived, is a tedious series of computations, interpolations, and extrapolations. This is no fault of the methods of aerological reduction, for these complexities arise naturally through the character of the recorded data and in the reduction of the kite observation to the epoch of the computation. The chief difficulty lies in knowing the magnitude of the effect of pressure and temperature variations between the time of computation and the time when the kite attained the level in question.

However, the values of barometric pressure corresponding to 8 a. m., 75th meridian time, have been prepared with scrupulous care by members of the Aerological Division of the Weather Bureau and subjected not infrequently to review and check.

Frequency distributions of residuals.—During the three months, there was made at the six aerological stations of the Weather Bureau, a total of 251 kite flights yielding pressure values for the two selected levels suitable for comparison with computation. After rendering these values as nearly as possible representative of 8 a. m. (75th meridian time) conditions, they were compared with the computed values, and the difference was regarded as negative in sign when the computed pressure was less than the observed, and positive when the computed pressure was greater. Classifying these residuals by hundredths of an inch, frequency distributions have been obtained. Figure 1 contains curves of the frequencies of errors of the several magnitudes for the two levels separately and combined, using data from all the stations. The principal features of these curves are:

(1) For the 3281-foot level, there are no errors in excess of 0.1 inch. The mode of the curve is at the zero class, but the curve is slightly asymmetrical, showing a larger number of negative residuals than positive.

(2) For the 6,562-foot level, the range of error is somewhat less than twice that of the lower level. This is to be expected from the nature of the hypsometric equation, in which the length of the reduction column is an important term. Other conditions being equal, a given error in the mean temperature of the air column will produce, in the United States east of the 100th meridian where the longer air column is nearly twice that of the shorter, an error in pressure at the upper level nearly twice the magnitude of that at the lower level.

The curve is nearly symmetrical, but has its mode in the -0.03 class. From this it would appear that, during the period of the observations, the temperature arguments should have been, in general, somewhat higher. This would not decrease the number of large residuals but would simply shift the curve to the right. A large number of these negative residuals was contributed by the comparisons of data from Due West, S. C. This station has been established since the method for computing was devised and, as a consequence, none of its data has contributed to the original investigation. The comparisons for Due West are, therefore, on a somewhat different footing, as will be explained later.

(3) When the residuals for the two levels are combined, the curve has its mode practically in the zero class but is somewhat skew, with an excess of negative values. This curve, which is simply the sum of the two mentioned above, derives its characteristics very obviously from the features of its components.

Individual station histograms.—Since it appears that more is to be learned through dividing the data into groups than by studying them *en masse*, it is desirable to subdivide the curves of figure 1 into separate station groups. When thus subdivided, the number of observations becomes too small to subject to statistical investigation. Indeed, it has been deemed advisable to present in the station histograms only the combined residuals from both levels. These histograms are given in figure 2.

In spite of the paucity of data, there is a certain obvious geographical influence operative in the distribution of residuals in the several diagrams. Stations in lower latitudes show extremes larger on the negative side than do the northern stations. Drexel, Nebr., with its large number of observations, shows an almost symmetrical distribution; Ellendale, N. Dak., shows the largest positive residuals; and Groesbeck, Tex., the most southerly of the stations, the largest negative errors. Owing to the unique characteristics of Due West, S. C., explained above, we may, for the moment, disregard its histogram.

Why should the southern stations yield a larger number of negative residuals than the northern? It is true that in the original study, the number of available kite observations which could be utilized for formulating the reduction method was greatest from Drexel and Ellendale; but, if the negative tendency at Groesbeck, for instance, were the result of nothing other than poor estimates of the mean temperature of the air column, one should expect that the distribution of errors, however wide, should follow the Gaussian law. The cause seems to lie rather in the geographical and seasonal characteristics of temperature at the particular stations.

[2] Another regrettable example of the confusion arising from the use of two systems of units is found here. The original papers, in which the method of making these free-air maps was described, employed metric units exclusively, because the aerological data, which were fundamental to the study, were thus tabulated. When it became necessary to make the application of the method at the regular stations of the Weather Bureau, it was desirable to render the maps in English units, both because of the familiarity of the observers with these units, and because of the necessity of having the maps readily comparable with the sea-level map. Consequently, in this paper, it has been decided to use the English units primarily, giving the metric equivalents in parentheses.

[3] Meisinger, C. Le Roy: *The preparation and significance of free-air pressure maps for the central and eastern United States.* Washington, 1922. An extended abstract of this SUPPLEMENT appears under the same title in MO. WEATHER REV., Sept., 1922, 50: 453-468.

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Since negative errors in the mean temperature of the air column are productive of negative errors in reduced pressure, it appears that the southern stations must possess characteristics that will produce such negative errors occasionally and more frequently than northern stations. Such errors may result from: (1) An underestimation of the difference between the surface temperature and the mean temperature of the air column; or, (2) a surface temperature that is abnormally low owing to radiation conditions; local conditions, such as exposure of thermometers; or thermal peculiarities associated with particular wind directions.

For instance, consider Groesbeck (which yielded the largest number of large negative residuals) in the light of the surface wind direction current at the time of the reduction. Of the 17 cases of residuals at the 6,562-foot (2 kilometer) level of −0.1 inch or greater, 6 occurred with southwest winds, 5 with south winds, one each with the other winds, except west, and one with a calm. The largest residual, −0.18 inch, occurred with a southwest surface wind. An investigation of the vertical temperature gradient as observed at Groesbeck by kites on the morning of January 10, 1923, the date of this large discrepancy, reveals an inversion of extraordinary magnitude. The barometric situation at the surface showed high pressure to the south of the station. The weather was clear and the surface winds light. At the inversion level, the wind was west-southwest and of greater speed. Surface temperature measured simultaneously at Palestine, Tex., the nearest station reporting daily to Washington, was 46° F., as compared with 38° F. at Groesbeck. The exposure of thermometers at Groesbeck is 11 feet above the ground, while at Palestine these instruments are on a roof 64 feet above ground. These temperatures indicate, therefore, that the low pressure computed for the upper level was not so much the result

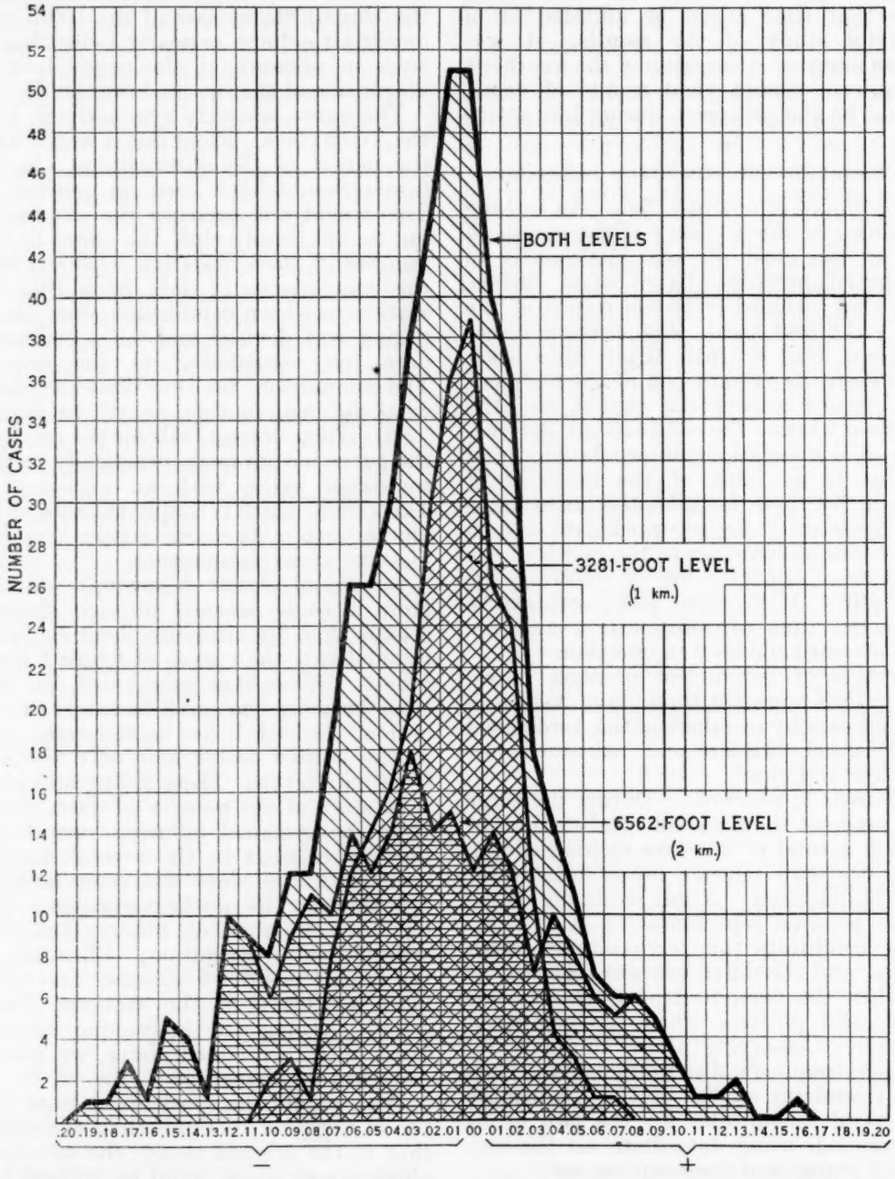


FIG. 1.—Frequency distributions of differences between observed and computed free-air pressures for the 3,281-foot level and 6,562-foot level, and for both levels combined. Data obtained from the six aerological stations of the Weather Bureau during the winter months of 1922–23.

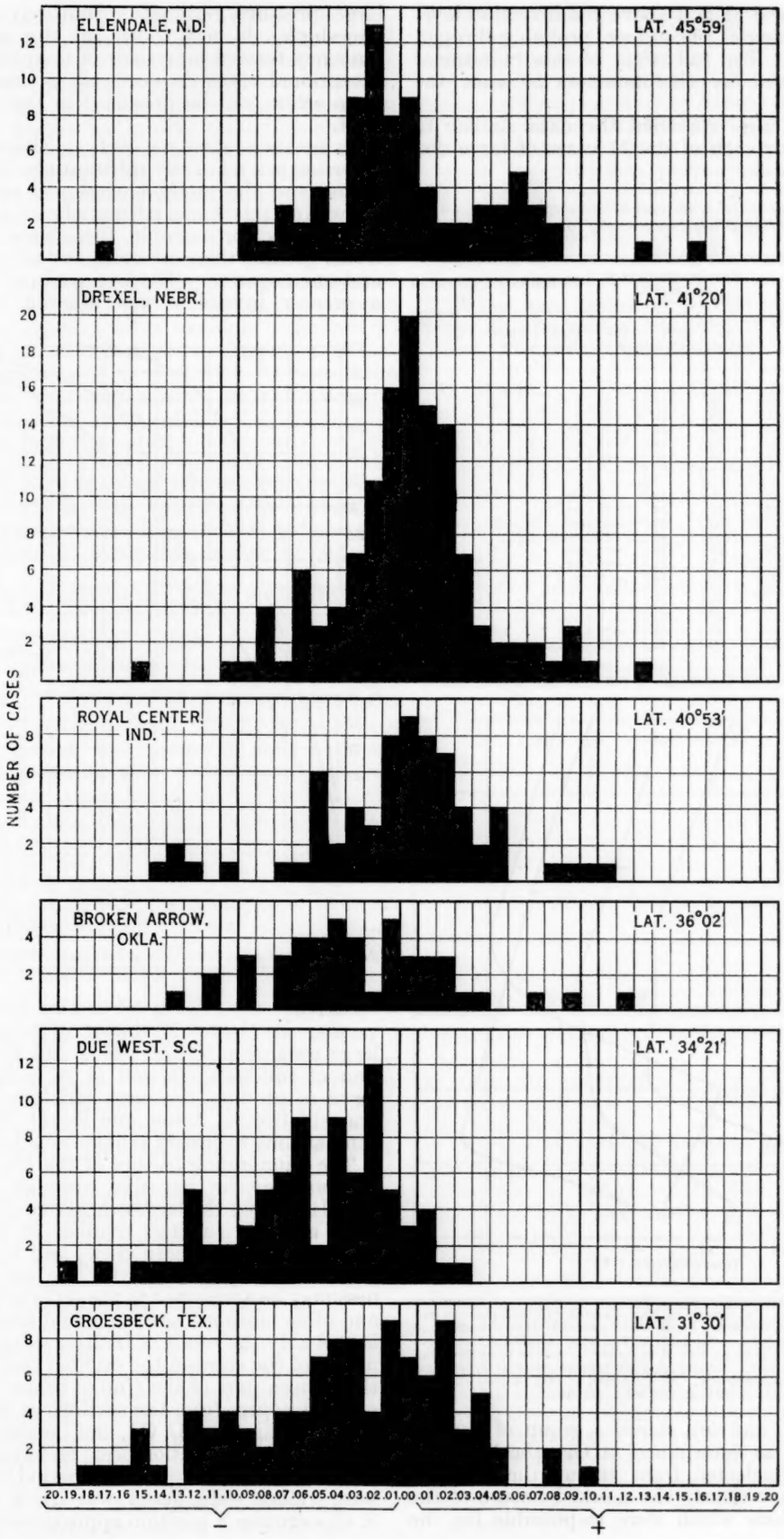


FIG. 2.—Frequency histograms for the six aerological stations of the Weather Bureau, showing the number of cases of differences of different magnitudes between observed and computed free-air pressures; both levels combined.

of warm air introduced at and above the inversion level as of an unusual cooling at the surface, probably through nocturnal radiation. The full effect of this radiational cooling was registered by thermometers so near the surface.

In Table 1 have been classified the data similar to those given above for each of the 17 cases of large discrepancies at Groesbeck.

TABLE 1.—*Temperature and wind conditions at Groesbeck, Tex., upon the occasions of the 17 largest negative errors of computation.*

Date.	Error.	Mean temperature of air column.			Surface wind.		Difference between Palestine and Groesbeck.[1]
		Observed.	Computed.	Difference.	Direction.	Velocity.	
1922.	*Inches.*	°F.	°F.	°F.		*M. p. h.*	°F.
December 15	−0.15	47	37	−10	n.	22	+3
20	−0.15	44	31	−13	e.	5	+5
22	−0.14	50	38	−12	sw.	7	+7
25	−0.16	56	42	−14	s.	3	+8
29	−0.15	54	41	−13	s.	8	+9
1923.							
January 4	−0.10	50	42	− 8	sw.	12	+1
6	−0.12	51	39	−12	ne.	7	+3
7	−0.12	60	50	−10	sw.	12	+3
8	−0.17	55	43	−12	calm.	.....	+7
10	−0.18	55	38	−17	sw.	11	+8
11	−0.11	61	51	−10	sw.	16	+1
17	−0.10	51	42	− 9	s.	7	+4
24	−0.12	47	37	−10	s.	10	−2
25	−0.11	54	45	− 9	se.	7	+3
February 17	−0.11	37	28	− 9	nw.	9	+1
19	−0.10	44	35	− 9	s.	8	+3
20	−0.12	50	40	−10	sw.	3	+5

[1] Positive sign (+) indicates higher temperature at Palestine than at Groesbeck.

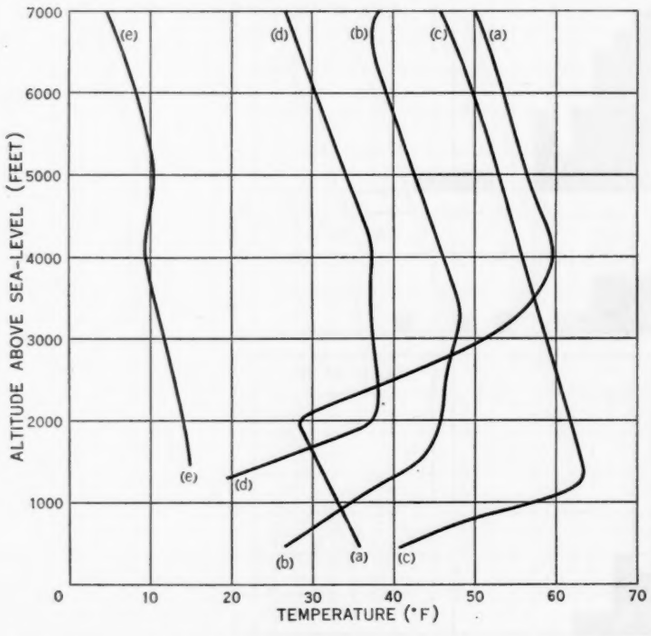


FIG. 3.—Specimens of vertical temperature curves determined by means of kites at several of the aerological stations. (*a*) Groesbeck, Tex., December 15, 1922; pressure error at upper level, −0.15 inch; surface wind, north. (*b*) Groesbeck, Tex., December 20, 1922; pressure error at upper level, −0.15 inch; surface wind, southeast. (*c*) Groesbeck, Tex., December 25, 1922; pressure error at upper level, −0.16 inch; surface wind, east-southeast. (*d*) Drexel, Nebr., January 20, 1923; pressure error at upper level, −0.15 inch; surface wind, west-northwest. (*e*) Ellendale, N. Dak., January 20, 1923; pressure error at upper level, +0.13 inch; surface wind, northwest.

Figure 3 (a), (b), and (c), shows a group of vertical temperature curves as determined at Groesbeck on the ascent of the kite, selected from among the dates in Table 1. These show clearly the marked nature of the temperature inversions which were responsible for the large pressure residuals. Southerly stations, such as Groesbeck, do not show, on the average, a marked tendency toward inversions of temperature. When such exceptional cases do occur, it is clear that abnormally large errors will be produced in the computed pressure aloft.

At northern stations, such as Ellendale, in winter, the inversion is a relatively constant condition in the morning hours, and the method employed in reducing pressure allows for this more adequately as a consequence. At this station, for example, there were only three cases of errors greater than 0.1 inch, two of which were positive and one negative. The two positive cases indicate that a greater inversion was allowed for than actually

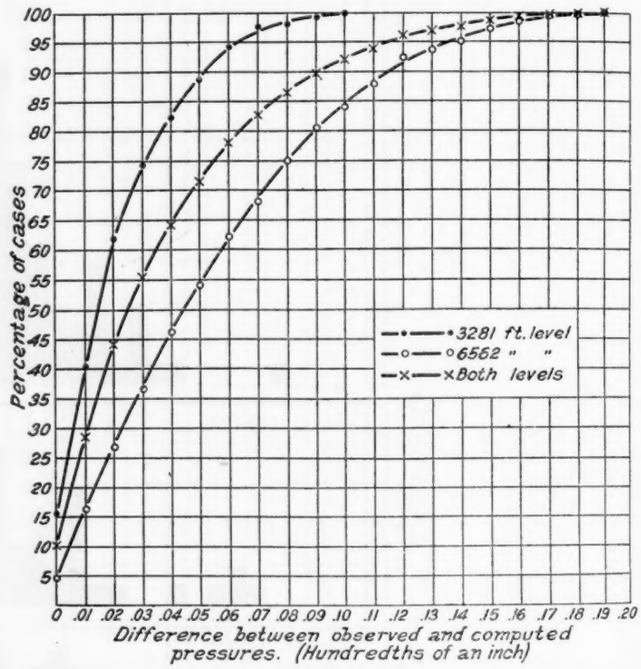


FIG. 4.—Curves for the two levels separately and combined, showing the percentage of errors of computed pressure of given magnitudes or smaller.

occurred. (See fig. 3 (e).) One case of a marked inversion at Drexel is shown in figure 3 (d). Drexel's large number of observations and symmetrical distribution of residuals, as well as its geographical situation, serve to produce the most satisfactory of all the histograms. Broken Arrow and Royal Center afford too few comparisons to justify reliable conclusions.

The outstanding feature of the Due West histogram is its tendency for negative residuals throughout. (Fig. 2.) It yielded the largest negative departure of any station, and the smallest number of positive departures. The curve is decidedly skew, and is also markedly displaced from symmetry with the zero class. The skewness may be attributed to the same causes as at Groesbeck and other stations, but the modal displacement to the left is probably the result of faulty geographical interpolation in one of the steps in the original research. The data for the eastern part of the United States were derived in the original papers from the stations at Mount Weather, Va. (near Washington, D. C.), and Leesburg, Ga. The record at the Virginia station was probably adequate for the purpose, but the length of the period upon which the Leesburg values were based was quite short. Due West, S. C., occupies a position approximately halfway between

the two mentioned above. If, on the average, the temperature values had been enough higher to shift the histogram several classes to the right, this station would have stood out as one of the best. One hestitates, however, to recommend that the values for this station be increased upon the basis of these three months' experience. It is wiser to withhold judgment upon the best solution of the problem until other evidence has been presented.

Thus far considerable attention has been devoted to the large residuals. But sight should not be lost of the large number of very satisfactory and accurate calculations. Figure 4 shows for the two levels separately and, in a third curve, combined, the percentage of residuals of any given value or smaller. The curves take no account of the sign of the residual. For example, reference to the curve for the 3,281-foot level shows that about 89 per cent of all the computations were within 0.05 inch of the observed value; for the higher level the percentage is about 54, and for the two levels combined it is about 72. When it is recalled that the isobars on the daily weather map are drawn for intervals of 0.1 inch and that, in telegraphing pressures, only the even hundredths are coded, errors of 0.05 inch will exercise but little effect upon the map. The first two curves are based on 251 values each, while the last is upon the combined number, or 502.

COMPARISONS OF OBSERVED AND ESTIMATED WINDS.

The difficulties of obtaining reliable standards of comparison from pilot-balloon data.—It has been pointed out that some clue as to the reliability of the free-air maps may be adduced from the comparison of estimated wind directions, based upon the gradient wind relations, with winds actually observed by means of pilot balloons. Here, as in the case of kite data, the comparison is not direct, and, moreover, there are several sources of disagreement that are quite impossible of elimination and yet which may apparently, but not really, throw discredit upon the usefulness of the maps for purposes of estimating the wind direction.

In the first place, the theory of the gradient wind states that the wind direction, except so far as it is influenced by friction or viscosity, is perpendicular to the gradient at the level in question. A synoptic chart gives an instantaneous picture of the pressure distribution but gives no clue as to the true horizontal trajectory of an air particle unless the whole barometric formation is stationary—a condition which seldom occurs in nature. Nevertheless, the agreement between the direction of the observed wind at a given level and the trend of the isobars at the same level is usually sufficiently close to permit of a satisfactory determination of the general drift of the air.

Thus, in these comparisons, the estimate of wind direction was based entirely on the above-mentioned assumptions, and it is to be supposed, therefore, that, in the case of rapidly moving formations or those in which the intensity was changing rapidly, many discrepancies between observed and estimated winds must occur.

In addition to the complexities introduced into the comparison by the gradient wind assumptions, there is the further question as to the degree to which the pilot-balloon observations themselves are representative of the air drift at a given level. It should be remembered that pilot-balloon flights give but momentary indications for each level, since the balloon is constantly ascending. Moreover, under variable or rapidly changing conditions, two ascents separated by a short time interval may reveal winds varying in direction by several points at the same level. In general, this is true especially in the case of light winds, and on a warm summer day all manner of vagaries, real and apparent, may be introduced into the horizontal trajectory of the balloon by convective forces. Again, difficulties may be encountered in attempting to read from the altitude-direction curve the direction corresponding to certain arbitrary levels, such as those chosen for reduction purposes. The winds may have been turning rapidly just at the level in question, so that a small difference in elevation would show a quite different wind direction. Figure 5 shows a series of altitude-speed and altitude-direction curves in which this is clearly brought out.

It has been necessary to make estimates for station lying on the western frontier of the computations, an these estimates were probably in greater error tha

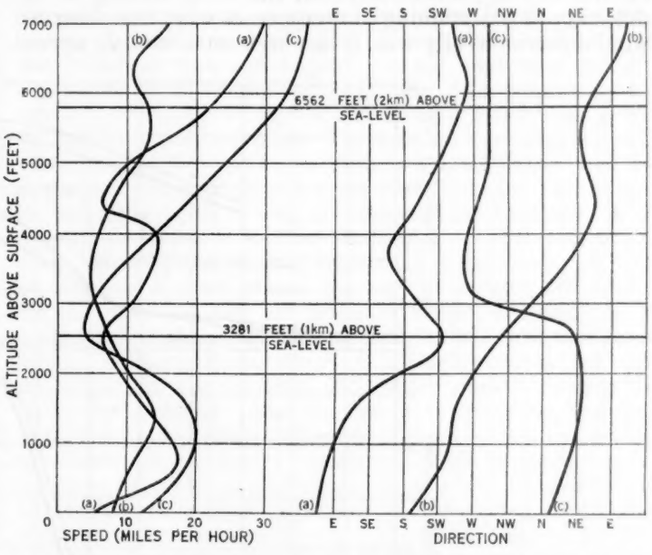


FIG. 5.—Altitude-velocity and altitude-direction curves for observations made by pilot balloons at Broken Arrow, Okla., showing examples of rapid turning of wind direction at certain levels, and the difficulty of determining at such elevations the true drift of the wind.

stations lying within the network, since the proper westward extension of the isobars was uncertain.

These factors all tend toward confusion in the determination of an absolute standard of accuracy in wind direction.

How the estimates were made.—The method used in arriving at the errors of estimation of free-air wind direction was as follows:

(1) Having completed maps for the two levels for a given date, a form, carrying as its first column a list of pilot-balloon stations of the Weather Bureau, the Army, and the Navy, was entered with the estimated direction of the wind for each station and level. This, it will be noted, was done in every case before actual observational material had yet been received, and was, therefore, entirely free from bias or influence which might unconciously arise if observed direction arrows had been plotted before the estimate was made.

(2) Upon completing this table for the period of a month, it was handed to the balloon section of the Aerological Division, where there were entered, for all stations at which observations were made at the required time of day, the direction recorded upon the observational form. All directions, both estimated and observed, were given on the 16-point scale. The observed wind speed was also entered.

(3) The classification of the errors of estimation was then made in the following manner: Facing the direction of the observed wind, the number of points on the 16-point scale, either to right or left, between this direction and that estimated was determined. For example, suppose a west wind was observed and a northwest wind was estimated: Facing the west, the northwest wind would be two points to the right in error. The observed velocity was also recorded in a class corresponding to a 2-point error to the right. Thus was formed a frequency table of 16 classes corresponding to the number of points of difference between the observed and estimated wind. The velocities also were tabulated in this way so as to make class averages possible.

What constitutes a correct estimate?—One is next faced with the problem of determining what shall constitute satisfactory agreement between the two. Owing to the difficulty of determining in many cases what the observed wind direction really was, it has been unanimously agreed among those with whom this matter was discussed *to define as correct an estimate that fell one point either side of the observed wind on the 16-point scale.* Successively, to either side of this class, the errors were designated as 1-point, 2-point, etc., on the same scale. In this way, the two classes of 7-point error coincide and represent the maximum possible error of estimation.

Error frequencies in wind direction.—In the lower part of figure 6 are shown two curves, one corresponding to the higher and one to the lower level. These curves show the percentage of errors falling within different classes, as defined above. The relatively high maxima of these curves as well as the sharp decrease of ordinates on either side of the correct class show at once the high degree of accuracy of estimation.

Errors in wind direction are not serious unless the velocity of the wind is high. Wind directions in nearly calm conditions have no significance. Therefore, in considering errors in estimating direction, one must also have regard to the corresponding velocity. In the two curves at the top of figure 6 there is shown for the two levels the average velocity of the wind, in miles per hour, corresponding to the several classes of errors. Owing to the very small number of large errors, it is apparent at once that the mean velocities at the extremes of the diagram would hardly be comparable with those at the center. Hence, the velocity curves were discontinued at class 4, although the points were plotted. *It is clearly seen that greatest accuracy is associated with highest velocity of the wind.* In these cases the wind velocity was about 30 miles per hour for the correct class, falling off to about 15 miles per hour at the points of discontinuance of the curves.

The two curves passing through the center of the diagram give the values of the square root of the number of observations upon which the means of the velocity are based. Since this quantity gives a measure of the relative value of the means, it is seen that the more accurate estimates are associated with more reliable mean velocities. Indeed, the ordinates of the curves at the extremes are less than 1/25 those in the center. It is reasonable to suppose that if enough large errors of estimation were available to give reliable means of velocity, those means would fall very low near the ends of the diagram.

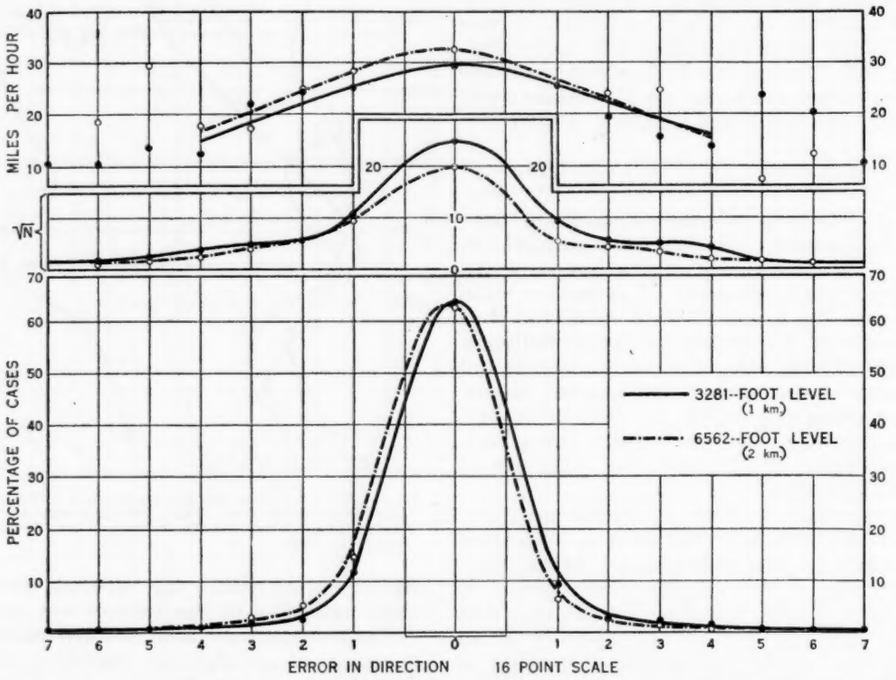


FIG. 6.—Upper section: Mean wind velocity corresponding to the several classes of error in estimating free-air wind direction. Middle section: The square root of the number of observations upon which the upper curves are based. Lower section: Curves of percentage frequency of occurrence of errors of different magnitudes in estimating free-air wind directions.

It has been noted in this figure that the curves for the two levels are slightly displaced, the upper curve lying to the right of the lower. The reason for this will not be investigated, owing to the minor practical importance of the point. It is suspected that it is associated with the effect of the eastward motion of translation of pressure systems introducing a component into the motion of air within the system.

It is more significant that the curve representing the accuracy of estimation at the upper level is almost identical with that for the lower. This shows that, in

spite of the lower degree of accuracy indicated in the pressure computations for the upper level, compared with those for the lower, the accuracy of estimated wind direction at the upper level is of quite as high degree as that at the lower. This is a highly important feature of this diagram.

Figure 7 shows in the heavily-drawn upper curve the percentage of cases in which the error was a given number of points or less, the number of points being designated on the axis of abscissae. In this diagram, as in figure 4, no distinction is made between errors to right or left. Nor are the levels separated, for it was found that the percentage of accuracy for the two levels was so nearly identical in each class that the curve representing the mean of the two is wholly adequate. It is seen that 63 per cent of the estimates were correct and that 91 per cent were within two points of error. The two curves

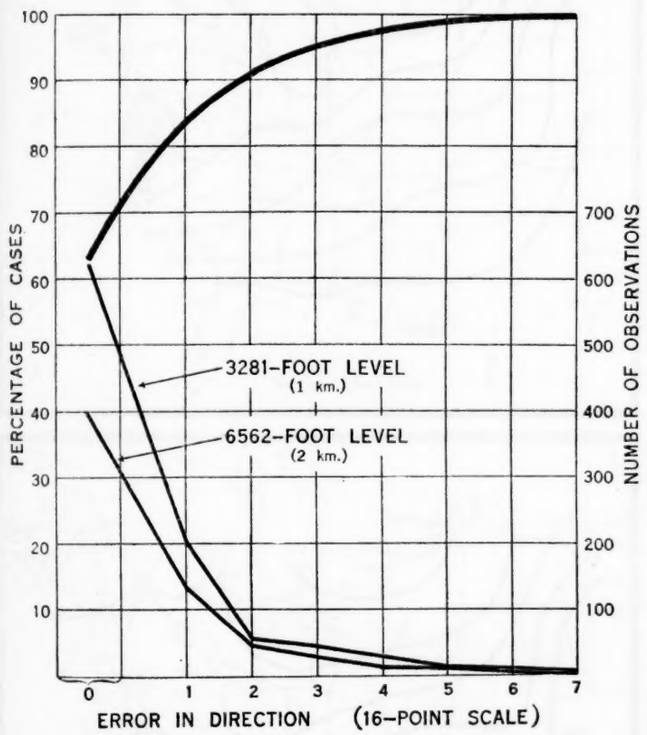


FIG. 7.—Upper curve shows the percentage of errors of estimated free-air wind direction of given magnitudes or smaller. Lower curves give the number of observations for the two levels upon which the upper curve is based.

in the lower part of the figure show the number of observations in the several classes as indicated on the scale of ordinates at the right. For the lower level a total of 984 comparisons was made; for the upper level the number was 637.

THE EFFECT OF PRESSURE ERRORS ON THE MAPS.

The exposure of thermometers and its effect upon the free-air maps.—One of the important points made in previous papers on this subject concerned the inconsequential effect upon the horizontal pressure gradient in the free air of temperature errors, provided errors of similar magnitude were made at adjacent stations. This argument is intrinsically sound. Nevertheless, it has been found that the influence most active in preventing similar errors at adjacent stations is not the factor applied to the surface temperature to obtain the mean temperature of the air column, but the surface temperature itself, owing to the non-uniform exposure of thermometers. Thus, on mornings following still, clear nights, or at the times of a cold wave, the thermometers at city stations roundabout aerological stations may register several degrees higher than the latter. Under such conditions, the resulting reductions are more nearly correct at city stations than at kite stations, and irregularities in the isobars occur in the vicinity of the aerological stations.

An interesting demonstration of this difference in current temperatures between near-by stations when the thermometers are differently exposed is to be found between Drexel and Omaha, Nebr.; and between Groesbeck and Palestine, Tex. Records for the month of January, 1923, only have been examined, but they show clearly what a more exhaustive investigation probably would disclose to a nicety, namely, that there is an approximately linear inverse relation between the velocity of the wind at the aerological station and the current temperature difference between the two stations. In other words, high wind velocity is associated with small difference of temperature (because of turbulence) and conversely. No variation with wind direction was so apparent. Therefore, when the kite station values are in harmony with those of surrounding stations, it is found that there is higher wind velocity and less difference between the current surface temperatures. Thus, at times of largest errors, the city exposures are better for the purpose than are those at aerological stations.

At the outset, it may seem paradoxical that the aerological stations from which the original data for the investigation were derived should be found less suitable than city stations. But the reason is apparent, namely, that the city station temperatures on these particular occasions are in better agreement with average conditions at aerological stations than are the temperatures at aerological stations themselves. Moreover, if all the stations where these free-air reductions are made were aerological stations, the map would probably not be so seriously affected. But since they are not, it is necessary for the minority to yield.

How may the situation be remedied?—The following schemes suggest themselves in consideration of means to prevent the occurrence of large residuals when comparisons are made with observed pressures, and also to produce more accurate maps:

(1) To correct the aerological station temperature tables by amounts which would bring them into accord with surrounding stations; or,

(2) To eliminate the aerological stations from the network, using only regular Weather Bureau stations.

There is hardly justification for the first plan in such tests as this, based upon a single season of comparisons. Next winter may be singularly free from such inversions as were productive of large negative errors during the present season. The significant point is that, in general, the temperature differences between city and country exposures were small except when large pressure discrepancies occurred at the free-air levels. Therefore, it seems that the second suggestion, i. e., the elimination of aerological stations from the network, would yield the more satisfactory maps.

The effect of occasional large errors on the map.—Granting occasional large computational errors, what will be the effect on the map? This question is not raised to condone the errors, for the effort and desire are for the elimination of error so far as possible, but to examine qualitatively the results of the comparisons.

A scrutiny of the various dates when comparisons of pressure were made indicates that December 22, 1922, was the occasion when several of the largest errors of which we have knowledge occurred simultaneously at the aerological stations. A map of this date must be a fair example of just how seriously the isobaric distribution is affected. Figure 8 shows for sea-level, and for the 6,562-foot level (maps A, B, and C) the barometric charts for the date in question. Map A is drawn from the *complete list of stations as reported by post card.* Map B is based upon the *regular Weather Bureau stations only*, aerological stations being eliminated. Map C results from using the pressures *measured by kites*, together with those computed at regular Weather Bureau stations. In other words, the data submitted on post cards from city stations have been used in each of the maps; but the aerological stations have been varied, using first the computed pressure; second, no values at all; and, third, the observed values.

In map A there is a questionable-looking southward loop of the isobar about Royal Center, Ind. In map B the loop is eliminated, and practically no change results elsewhere. In map C the pressure at Broken Arrow, Okla., and Groesbeck, Tex., are increased so as to produce a northward projection of high pressure from the Gulf region. The Royal Center loop is not apparent.

In general, these maps do not disagree as to the major features. In limited regions, such as central Texas, it is

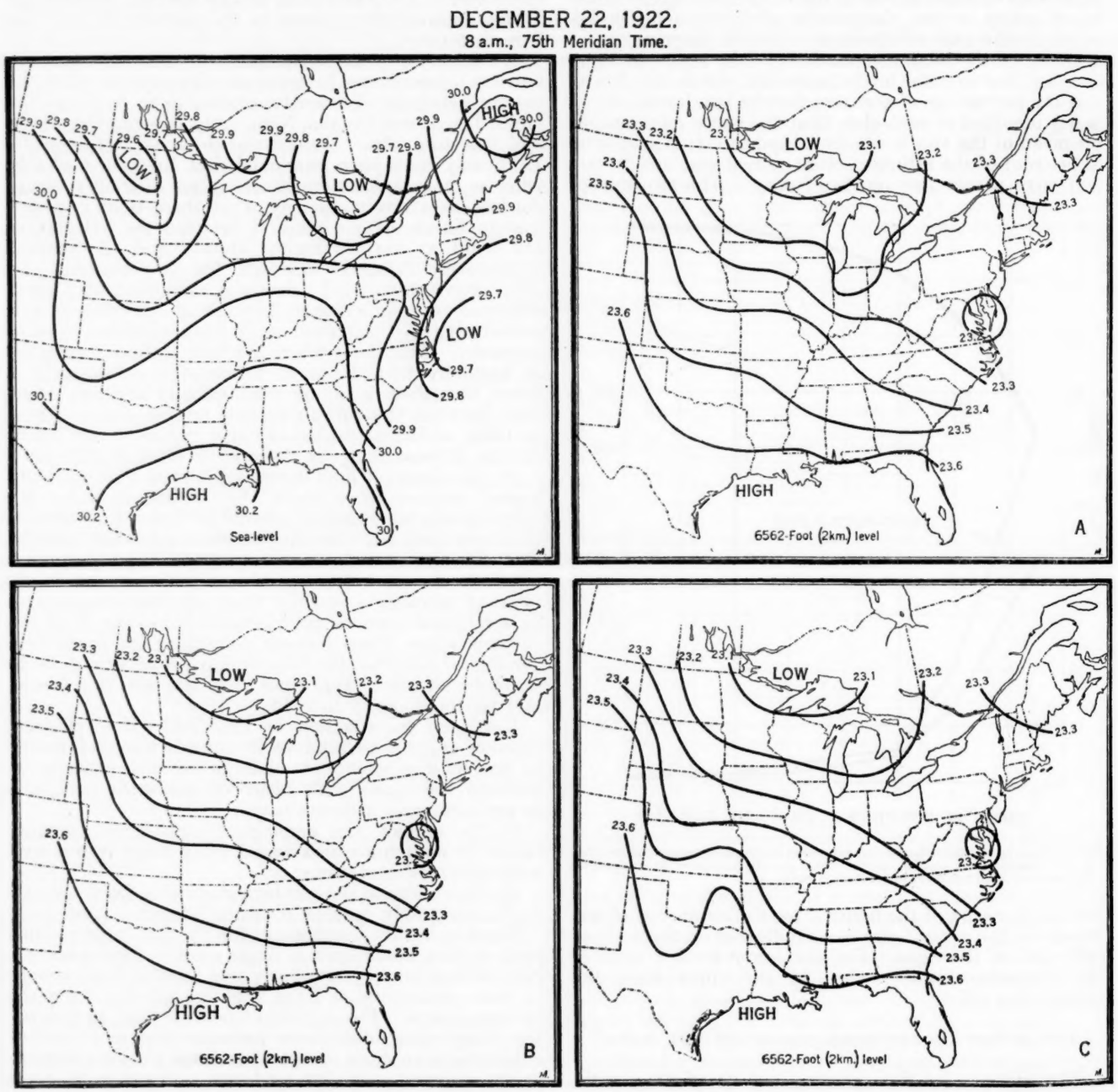
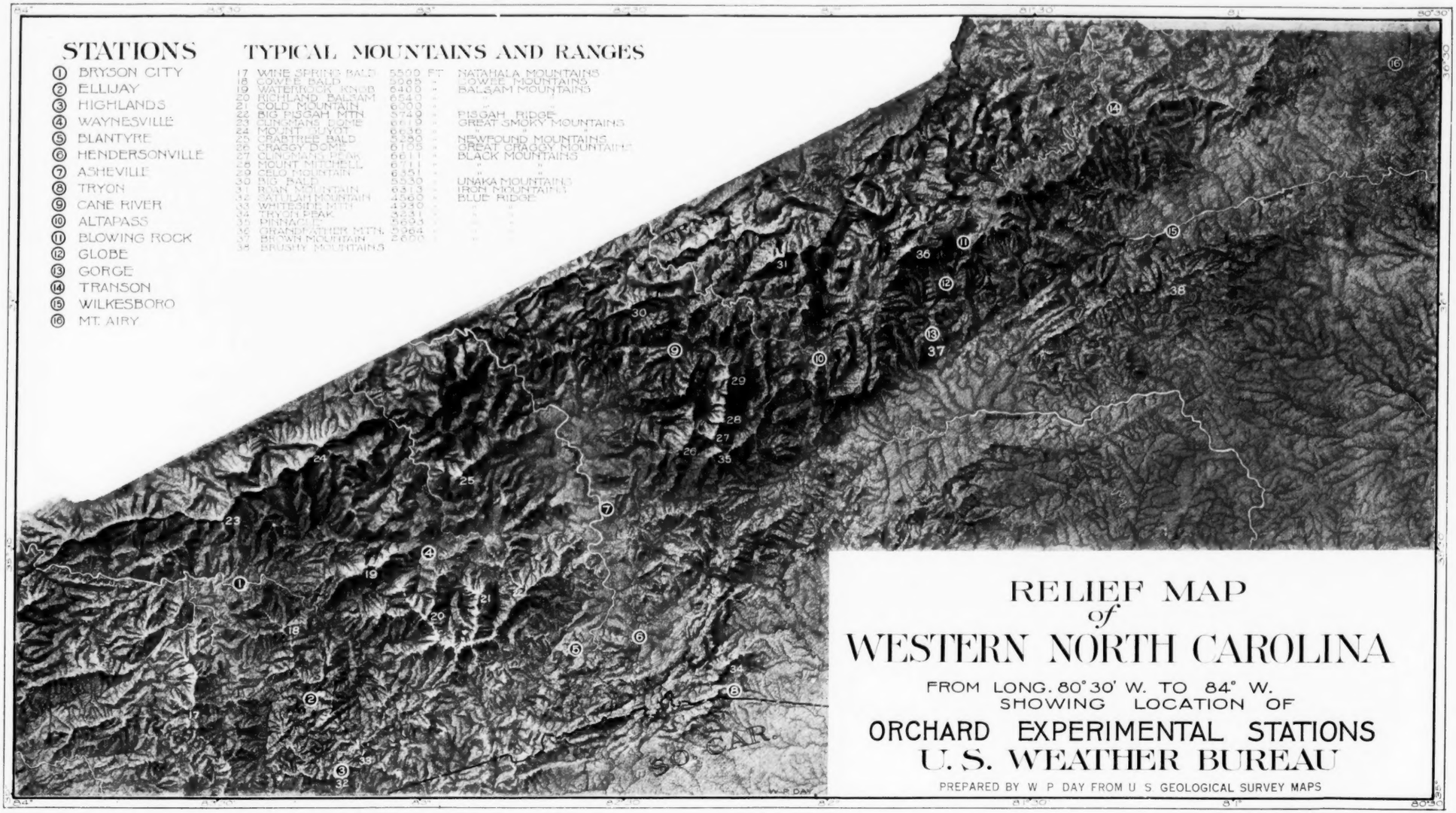


FIG. 8.—Sea-level and 6,562-foot-level maps for December 22, 1922, 8 a. m., 75th meridian time. For differences in drawing maps A, B, and C, see discussion in text.


STATIONS
① BRYSON CITY
② ELLIJAY
③ HIGHLANDS
④ WAYNESVILLE
⑤ BLANTYRE
⑥ HENDERSONVILLE
⑦ ASHEVILLE
⑧ TRYON
⑨ CANE RIVER
⑩ ALTAPASS
⑪ BLOWING ROCK
⑫ GLOBE
⑬ GORGE
⑭ TRANSON
⑮ WILKESBORO
⑯ MT. AIRY
TYPICAL MOUNTAINS AND RANGES
17 WINE SPRING BALD 5500 FT. NANTAHALA MOUNTAINS
18 COWEE BALD 5065 " COWEE MOUNTAINS
19 WATERROCK KNOB 6400 " BALSAM MOUNTAINS
20 RICHLAND BALSAM 6540 " "
21 COLD MOUNTAIN 6000 " "
22 BIG PISGAH MTN 5749 " PISGAH RIDGE
23 HUNGRY DOME 6610 " GREAT SMOKY MOUNTAINS
24 MOUNT GUYOT 6636 " "
25 CRABTREE BALD 5280 " NEWFOUND MOUNTAINS
26 CRAGGY DOME 6195 " GREAT CRAGGY MOUNTAINS
27 CLINGMANS PEAK 6611 " BLACK MOUNTAINS
28 MOUNT MITCHELL 6711 " "
29 CELO MOUNTAIN 6351 " "
30 BIG BALD 5530 " UNAKA MOUNTAINS
31 IRON MOUNTAIN 6313 " IRON MOUNTAINS
32 CATULLA MOUNTAIN 4500 " BLUE RIDGE
33 WHITESIDE MTN 4930 " "
34 TRYON PEAK 3331 " "
35 PINNACLE 5693 " "
36 GRANDFATHER MTN. 5964 " "
37 BROWN MOUNTAIN 2670 " "
38 BRUSHY MOUNTAINS
RELIEF MAP
of
WESTERN NORTH CAROLINA
FROM LONG. 80° 30' W. TO 84° W.
SHOWING LOCATION OF
ORCHARD EXPERIMENTAL STATIONS
U. S. WEATHER BUREAU
PREPARED BY W. P. DAY FROM U. S. GEOLOGICAL SURVEY MAPS
W. P. DAY
SC.
GA.

50612—23. (To face p. 199.)

clear that under such conditions the wind estimate from either map A or B would be somewhat in error, assuming the gradient-wind conditions obtained. Nevertheless, when we consider that the difference between the sea-level map and those for the upper level is so striking, and that the differences between individuals A, B, and C are so small, there is little doubt that the important and significant features of the true isobaric distribution at the upper level are depicted. The anomalous loops, such as that about Royal Center, Ind., on map A, when based on a single station, are easily recognized as erroneous and allowance can be made. But this should not be necessary, and it is contended that if the type of map exemplified by map B were used—that is, if the aerological stations were not used but near-by regular stations substituted, so far as possible—the resulting maps would be highly accurate and dependable so far as free-air barometric gradients are concerned. This procedure is suggested in further activities of this character.

CONCLUSION.

An effort has been made in this paper to set forth clearly and impartially the results of a statistical examination of a three months' series of free-air pressure maps. It was first shown that a very large percentage of comparisons between observed and computed pressures lay within small error limits, better results being obtained at the 3,281-foot than at the 6,562-foot level. With all the uncertainties of the gradient-wind assumptions and the short-period vagaries of the observed wind, an extremely high percentage of agreement (practically the same at both levels) was found between the wind estimated from the isobaric charts of the free air, and that observed by pilot balloons. The average velocity of the wind falls off appreciably with the larger errors of estimated wind direction, so that, usually, when a serious error of estimation is made, the velocity of the wind is so small as to render the wind direction inconsequential. This is especially significant in estimating winds for aircraft. On the poorest day available the difference between maps drawn with and without the aerological stations and also with the observed pressures at aerological stations was so small that little-differing conclusions might be drawn from each.

It was stated in the beginning that if the maps could be proved to be accurate their scientific value would stand unchallenged. If this discussion of the accuracy of the maps has been convincing, it will be seen that there is here provided a means of knowing, quite independently of current aerological observation, the current wind conditions in the free air over large areas of the country, whether the weather be clear or cloudy. At present, the pilot-balloon stations telegraph the free-air winds as soon as possible for the use of the forecaster. Often such observations are impossible because of cloudiness, rain, snow, or fog. When used in conjunction with the aerological reports, these charts should constitute a most valuable means of weaving the various reports into a continuous pressure system, a speculative and uncertain matter at present. The advantage of such maps for aviation is obvious.

It would be quite impossible, even if it were within the scope of this paper to discuss the point, to indicate the precise manner in which these charts should be utilized in general forecasting. That must be determined by actual trial; and by actual trial is meant day-to-day telegraphing of free-air pressures in order that they may be available to the forecaster for comparison with other data while the current weather situation is fresh in mind. It is common knowledge that the growth of aviation implies increasing demands upon the Weather Bureau. Is it not essential, therefore, that every means be employed to acquire experience and familiarity with actual physical processes in the free air, while the science of aeronautical meteorology is yet in its infancy? The day will come when this knowledge *will* be required, and since it can only be acquired by experience it is the exercise of foresight to make a practical trial of the maps. This trial should continue for at least a year, and, during that time, all possible constructive criticism should be brought to bear upon the maps.

Acknowledgments.—The large amount of observational data used for comparison purposes in this paper could not have been assembled without the enthusiastic assistance of Mr. L. T. Samuels, Mr. W. C. Haines, and their associates in the Aerological Division of the Weather Bureau. They manifested considerable personal interest in the results and contributed many helpful suggestions; they were particularly prompt, also, in supplying data and in ferreting out the facts concerning suspected errors. For this cooperation the author records his earnest thanks.

COX ON THERMAL BELTS AND FRUIT GROWING IN NORTH CAROLINA.[1]

By ALFRED J. HENRY.

[Weather Bureau, Washington, D. C., May 7, 1923.]

NOTE.—According to custom an abstract and review of MONTHLY WEATHER REVIEW SUPPLEMENT No. 19 is presented below. These SUPPLEMENTS contain the results of the more comprehensive studies made by Weather Bureau officials or others. They appear at irregular intervals and are generally too voluminous to appear in the REVIEW proper.

As a result of economies in printing that have recently become effective the edition of the SUPPLEMENTS is not large enough to supply the regular REVIEW readers. The SUPPLEMENT will be sent free, however, to those who may have a practical interest in the subject investigated, but only upon application, and so long as the bureaus' supply lasts. After that is exhausted applicants will be referred to the Superintendent of Documents, Washington, D. C. The price of this supplement is 50 cents.—EDITOR.

The phenomenon of the stratification of the air temperature over valleys and the inclosing slopes was brought to the attention of scientific men of the United States by Silas McDowell, of Franklin, Macon County, N. C., more than 60 years ago. McDowell was a farmer with leanings toward botany and geology, who spent his entire life in the mountain region of western North Carolina. His first published account of thermal belts or verdant zones, as he called them, appeared in the report of the Commissioner of Patents for 1861, and the substance of that report was later presented to the Philosophical Society of Washington (D. C.), by Dr. J. J. Chickering. The late Prof. John LeConte, of Berkeley, Calif., writing in *Science*,[2] confirmed McDowell's observations and added the statement that the ground in the thermal belts freezes in winter, a fact that might not be inferred from McDowell's description.

The explanation of the phenomena offered by McDowell would hardly be accepted at this time, but nevertheless

[1] Cox, H. J.: Thermal belts and fruit growing in North Carolina: with an appendix: Thermal belts from the horticultural viewpoint, by W. N. Hutt, former State horticulturist, MONTHLY WEATHER REVIEW SUPPLEMENT No. 19.

[2] 1883, vol. 1, p. 278.

his observations, qualitative as they were, have since been fully confirmed. He also laid down the proposition that thermal belts must exist in all countries traversed by high mountains and deep valleys.

The evidence obtained by the use of kites and balloons clearly points to the fact that stratification of the atmosphere as regards temperature is not confined to mountainous regions, but also obtains over perfectly level surfaces on almost any winter night when the air is still. McDowell and other early observers used the mountains as a vantage ground to observe the phenomena, and in the absence of information to the contrary assumed that the mountains must be a causative agent in producing the stratification observed.

Fruit growers in North Carolina have been cultivating the apple and, in less degree, the peach for many years. These efforts have been attended in many cases by success and in other cases by failure. Immunity from frost damage on certain slopes has naturally directed attention to what, in the vernacular of the region, were known as "thermal belts," the term used by McDowell in 1858. Lacking definite quantitative measures of the differences between the temperature on the slopes that were immune from frost and those which were not, it is not strange that a former State horticulturist, Mr. W. N. Hutt, was led to remark:

> In making my trips over the State and in coming in contact with fruit growers, I kept up a constant quest for the elusive thermal belt, but, like an ignis fatuus, light and tenuous as the air, it always seemed to elude my grasp.

The above paragraph expresses the raison d'être for the investigation undertaken by the Weather Bureau at the request of the State authorities.

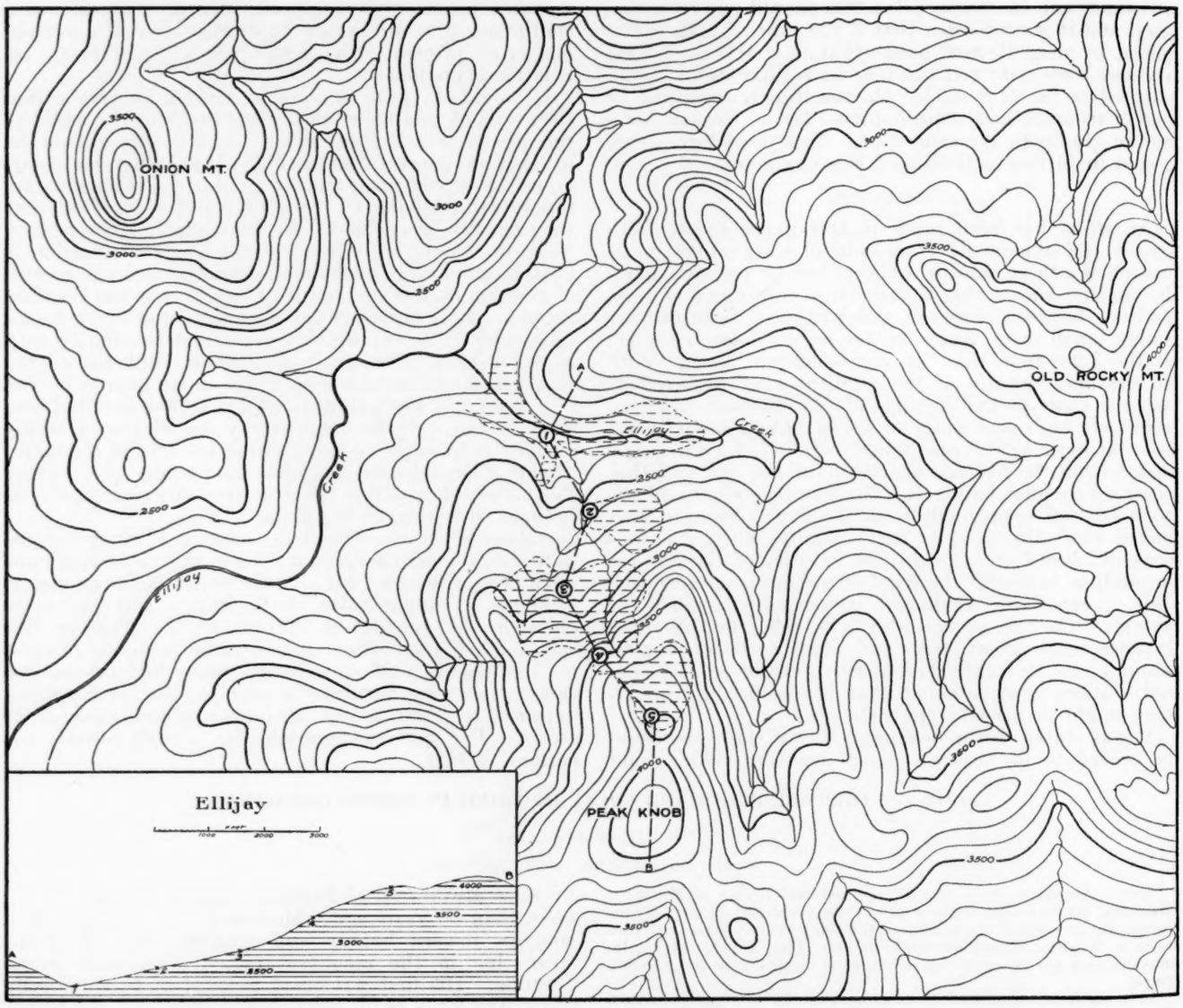


FIG. 2.—Ellijay, contour map and profile.

The results of this investigation are set forth in the publication under review. Observational work began in 1913 and was concluded in 1916, so that but four years are available for discussion. Unfortunately, the original compilations and the discussion were destroyed by fire while in transit between Washington and Chicago, and the entire work had to be done de novo.

The plan, in brief, contemplated the selection of a number of slopes of different aspect in the fruit growing districts of western North Carolina and to make systematic observations of temperature at different elevations

upon the slopes. Eventually 16 slopes were selected and individual observing points ranging from 1 to 5 were installed on each slope. The geographic location of the several slopes is shown on Figure 1.

In all, between 50 and 60 stations were in operation during the life of the experiment.

It is exceedingly difficult to present within the limits of this review a full abstract of the results of the four years' work, but it appears least objectionable to present the data accumulated on one of the most important slopes as an index to the complete report.

The slope selected is that of Ellijay, one of the longest of the experiment. The topography of the immediate region in which the stations are situated is shown in Figure 2 and the following supplemental verbal description is supplied:

ELLIJAY.

Chas. G. Mincy, Observer.—The Ellijay stations, on a steep northerly slope of a spur of the Cowee Mountains, the base station, No. 1, being in the valley floor of Ellijay Creek at an elevation of 2,240 feet, while the high station, No. 5, is on the summit of a knob 1,760 feet above the base and 4,000 feet above sea level. Station No. 1, in a field about 30 feet south of the creek, over grass plot, at a considerable distance from any trees; across creek to the north, steep high slopes, more or less broken, while to the south, slope abrupt near the valley floor; orchard at some distance south of shelter on northerly slope broken and uneven with natural terraces here and there; valley narrow and trending in east-west direction, almost entirely inclosed by mountains. Station No. 2, in orchard, on rather steep northerly slope with ferns and weeds on all sides, 310 feet above station No. 1; timber to north, northwest, west and southwest; cleared land directly to east, northeast, and southeast, and for some distance to the south, about 500 feet. Station No. 3, the home station, 620 feet above station No. 1, over sod in apple orchard on moderate slope though steeper above and below, slope broken up into ridges and hogbacks. Station No. 4, 1,200 feet above station No. 1, in clearing and on edge of steep northerly slope in corn and potato patch; brush about 16 feet to the west; some timber 100 feet to the west and southwest. In winter sun shut off during greater part of day. Station No. 5, 1,760 feet above station No. 1, a level field near the summit of a high knob, another prominence, Peak Knob, 180 feet higher than station No. 5, distant 1,800 feet to the south timber to the west, southwest and south, mostly dead, close by; abrupt slopes to the north and east. Ellijay Creek, near which station No. 1, stands, flows in a westerly direction through a narrow valley, and the slope on the north side is broken up into spurs and hogbacks. For a vertical distance of 1,760 feet between stations Nos. 1 and 5 at Ellijay, there is a horizontal distance of about 5,100 feet, equivalent to an average grade of 19°. The grade on some portions of the slope is more than 30°.

The most important observational material is undoubtedly that of the minimum temperature registered during each night of the observational period. The monthly means as summarized by the author are presented in Table 1.

TABLE 1.—*Monthly and annual average minimum temperatures, 1913–1916.*

[The differences between the averages at the base station and those of the respective slope stations may be seen by simple inspection.]

Principal and slope stations; elevation of base station above mean sea level.	Height of slope station above base (feet).	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Altapass:														
No. 1, base station, elevation 2,230	.....	[1] 31.1	[1] 29.1	[1] 31.5	[1] 44.2	52.8	58.4	62.5	61.3	54.0	46.3	36.6	29.8	[1] 44.8
No. 2, SE	250	[1] 31.5	[1] 29.6	[1] 31.3	[1] 45.3	54.0	59.2	63.1	62.1	55.5	48.2	38.4	30.2	[1] 45.7
No. 3 SE	500	[1] 31.4	[1] 29.3	[1] 30.8	[1] 44.5	53.6	58.6	62.7	62.0	55.3	48.0	37.9	29.7	[1] 45.3
No. 4, SE	750	[1] 29.4	[1] 27.3	[1] 28.9	[1] 42.3	51.8	56.7	60.5	60.1	53.3	46.6	36.2	27.8	[1] 43.4
No. 5, summit	1,000	[1] 29.1	[1] 27.0	[1] 28.8	[1] 42.1	51.0	55.8	60.2	59.5	52.5	45.2	35.4	27.4	[1] 42.9
Asheville:														
No. 1, base station, elevation 2,445	.....	32.3	28.8	32.9	41.8	50.7	56.6	60.3	59.8	52.6	44.6	34.4	28.8	43.6
No. 2, N	155	33.3	29.7	33.6	43.6	52.9	58.0	61.4	60.4	54.6	45.9	36.5	29.5	45.0
No. 2a, S	155	34.5	30.6	34.7	45.0	53.9	59.1	62.4	61.7	55.7	47.5	37.6	30.9	46.1
No. 3, N	380	33.9	30.1	34.1	44.7	54.9	60.0	63.2	62.3	55.6	47.9	38.8	30.8	46.4
No. 3a, S	380	34.5	30.4	34.4	45.4	55.2	60.1	63.4	62.6	56.3	48.4	38.8	30.8	46.7
Blantyre:														
No. 1, base station, elevation 2,090	.....	30.1	26.6	30.2	38.4	47.7	56.1	60.7	60.6	52.8	43.2	29.7	26.0	41.8
No. 2, NW	300	31.4	27.8	32.2	41.6	49.6	56.0	59.8	59.6	51.7	43.0	31.8	27.3	42.6
No. 3, NW	450	32.5	29.2	32.8	43.7	52.1	57.2	61.2	60.6	53.4	45.3	35.5	29.1	44.4
No. 4, NW	600	33.5	30.6	33.8	45.0	54.0	58.4	62.5	61.8	55.3	47.0	37.5	30.3	45.8
Blowing Rock:														
No. 1, base station, elevation 3,130	.....	30.0	26.6	30.2	41.2	50.2	56.9	60.6	60.4	53.6	45.4	35.0	27.2	43.1
No. 2, SW	450	30.0	26.4	29.9	42.4	51.9	57.2	60.9	60.4	53.8	45.8	36.8	27.6	43.6
No. 3, SE	450	27.2	23.4	27.6	37.1	46.1	53.3	56.8	56.3	48.4	42.2	29.6	24.0	39.3
No. 4, SE	625	29.0	25.3	29.0	40.5	50.2	55.9	59.9	59.0	52.4	44.6	35.0	26.2	42.2
No. 5, SE	800	28.0	24.6	28.0	39.6	49.8	55.6	59.2	58.5	51.6	43.8	33.8	25.2	41.4
Bryson:														
No. 1, base station, elevation 1,800	.....	[2] 31.3	[1] 27.4	[1] 28.3	39.4	48.5	55.7	60.0	59.8	52.6	43.1	[1] 30.7	[1] 26.5	[1] 41.9
No. 2, N	385	[2] 32.6	[1] 28.6	[1] 29.5	41.3	49.7	56.0	59.8	59.6	53.0	44.2	[1] 33.6	[1] 27.9	[1] 43.0
No. 2a, S	385	[2] 33.1	[1] 29.0	[1] 29.8	42.4	50.6	56.8	61.2	60.6	53.3	44.1	[1] 33.7	[1] 28.2	[1] 43.6
No. 3, summit	570	[2] 33.8	[1] 29.9	[1] 30.8	44.4	52.3	57.6	61.2	60.8	53.6	46.0	[1] 36.2	[1] 29.0	[1] 44.6
Cane River:														
No. 1, base station, elevation 2,650	.....	[1] 26.4	[1] 25.7	[1] 27.2	37.6	46.6	53.9	58.1	58.0	49.6	40.4	28.5	24.8	39.7
No. 2 N	190	[1] 29.9	[1] 27.2	[1] 28.9	40.9	49.6	55.4	59.1	58.7	51.3	43.0	33.7	27.6	42.1
No. 3, NE	400	[1] 29.5	[1] 26.1	[1] 27.9	41.3	51.0	56.2	59.8	59.4	52.5	44.4	35.2	27.3	[1] 42.6
No. 4, summit	1,100	[1] 28.8	[1] 26.9	[1] 27.1	41.0	51.3	56.7	60.2	59.6	53.1	45.3	36.3	27.2	[1] 42.8
Ellijay:														
No. 1, base station, elevation 2,240	.....	[1] 30.2	[1] 27.7	[1] 28.6	39.7	48.2	54.7	58.8	58.4	51.1	42.5	31.1	27.4	[2] 41.6
No. 2 N	310	[1] 31.1	[1] 30.0	[1] 30.5	42.6	51.0	56.6	59.9	59.0	52.0	43.7	33.8	28.6	[2] 43.7
No. 3, N	620	[1] 31.9	[1] 29.9	[1] 30.5	43.2	52.2	57.1	60.4	59.6	53.3	45.3	36.7	29.7	[2] 44.4
No. 4, N	1,240	[1] 32.8	[1] 30.8	[1] 30.8	45.4	54.8	59.4	62.1	61.2	55.3	47.7	39.1	31.1	[2] 45.8
No. 5, summit	1,760	[2] 32.6	[2] 29.6	[1] 28.6	[1] 44.2	[1] 54.0	[1] 58.4	[1] 60.9	[1] 60.0	[1] 54.7	[1] 48.1	[1] 37.7	[1] 28.6	[1] 44.9
Globe:														
No. 1, base station, elevation 1,625	.....	31.8	29.0	32.4	41.9	51.1	58.0	62.0	61.6	54.6	46.5	34.6	29.2	44.4
No. 2, E	300	33.4	30.6	34.3	45.1	55.0	60.5	64.1	63.5	57.0	49.3	38.6	31.2	46.9
No. 3, summit	1,000	33.6	30.4	33.8	46.0	55.9	61.2	64.6	63.5	57.2	49.7	39.8	30.8	47.2
Gorge:														
No. 1, base station, elevation 1,400	.....	30.8	28.1	32.3	40.5	49.3	56.8	61.1	61.0	53.9	45.2	32.8	27.9	43.3
No. 2, NE	290	30.6	27.8	32.0	41.2	50.2	57.2	61.0	60.8	53.6	45.1	33.8	28.6	43.5
No. 3, S	615	32.4	29.6	33.6	43.8	52.3	58.0	61.8	61.0	54.2	45.8	36.6	29.7	44.9
No. 4, N. (old); NE. (new)	840	33.0	30.2	34.4	45.6	54.8	59.7	63.2	62.4	55.9	48.0	39.1	30.6	46.4
No. 5, summit	1,040	33.5	30.9	34.4	46.9	57.0	61.4	64.9	63.7	57.7	49.9	41.1	32.0	47.8

[1] Three-year average. [2] Two-year average.

TABLE 1.—*Monthly and annual average minimum temperatures, 1913–1916*—Continued.

Principal and slope stations; elevation of base station above mean sea level.	Height of slope station above base (feet).	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Hendersonville:														
No. 1, base station, elevation 2,200		[1] 28.9	[1] 27.3	[1] 28.3	38.8	47.8	55.4	59.6	59.8	51.8	43.2	31.1	27.4	42.0
No. 2, E.	450	[1] 30.7	[1] 28.5	[1] 30.3	41.7	50.8	57.7	61.1	60.5	53.0	44.9	34.4	28.9	44.7
No. 3, E.	600	[1] 31.5	[1] 29.8	[1] 30.7	44.0	53.2	58.7	61.8	61.4	54.7	46.9	37.4	29.7	46.2
No. 4, summit	750	[1] 31.7	[1] 30.0	[1] 30.9	44.6	54.2	59.3	62.6	61.6	55.5	47.8	38.4	30.1	46.8
Highlands:														
No. 1, base station, elevation 3,350		[1] 32.2	[1] 28.9	[1] 30.4	44.2	53.2	58.3	61.6	61.0	55.2	47.0	38.0	30.7	45.1
No. 2, SE.	200	[1] 33.0	[1] 31.1	[1] 30.2	44.2	53.4	58.5	61.7	61.4	55.3	47.4	38.9	31.8	45.6
No. 3, SE.	325	[1] 26.8	[1] 23.4	[1] 24.4	34.6	43.4	49.4	53.5	53.0	45.7	38.0	27.7	23.4	37.0
No. 4, SE.	525	[1] 29.0	[1] 25.9	[1] 26.0	41.2	50.7	55.6	58.5	57.6	51.3	44.2	35.8	27.2	41.8
No. 5, SE.	725	[1] 28.6	[1] 25.7	[1] 25.4	41.5	51.4	56.5	59.8	58.7	52.6	46.0	36.8	28.6	42.5
Mount Airy:														
No. 1, base station, elevation 1,340		33.0	30.0	34.6	45.0	53.6	60.5	64.0	63.4	56.3	48.2	37.0	30.2	46.3
No. 2, W.	160	34.3	31.4	35.6	47.2	57.2	63.1	66.3	64.7	58.8	51.3	41.0	32.2	48.6
No. 3, E.	160	34.0	30.8	35.3	46.4	55.6	61.8	64.7	64.0	57.6	49.7	39.0	31.8	47.6
No. 4, summit	360	33.9	30.8	34.7	46.8	56.8	62.6	66.0	64.9	58.8	51.2	40.6	31.8	48.2
Transon:														
No. 1, base station, elevation 2,970		28.8	24.7	28.4	38.3	46.4	53.3	57.6	56.6	48.8	41.4	30.4	24.5	40.0
No. 2, W.	150	30.6	26.4	29.8	41.4	51.2	56.7	59.8	59.2	52.0	43.8	34.9	26.8	42.8
No. 3, W.	300	30.4	26.8	29.8	41.8	51.2	57.2	60.6	59.8	52.8	45.1	35.9	27.0	43.2
No. 4, summit	450	[1] 29.1	[1] 27.2	[1] 27.8	42.0	52.3	57.5	60.8	60.0	54.2	46.3	36.9	27.3	43.8
Tryon:														
No. 1, base station, elevation 950		34.7	32.3	35.9	44.7	54.8	63.0	66.7	66.3	58.5	50.6	37.3	32.8	48.1
No. 2, SE.	380	38.1	36.0	39.4	50.8	60.4	65.7	69.0	67.6	61.4	53.8	44.3	35.9	51.8
No. 3, SE.	570	37.6	34.8	38.1	49.7	58.8	64.2	67.5	66.4	59.9	52.2	43.0	34.4	50.5
No. 4, SE.	1,100	35.8	33.3	36.2	47.5	56.9	61.9	65.0	64.4	58.0	47.7	40.6	32.8	48.8
Wilkesboro:														
No. 1, base station, elevation 1,240		31.6	28.8	33.8	43.4	52.1	59.2	63.3	62.8	55.6	46.4	35.0	29.0	45.0
No. 2, N.	150	33.1	30.4	35.2	45.7	54.9	60.6	64.4	63.7	56.2	48.4	37.6	30.7	46.7
No. 3, N.	350	34.2	31.8	36.2	47.5	57.0	62.3	66.2	65.0	58.2	50.6	40.6	32.2	48.5
No. 4, W.	430	34.2	31.4	35.8	47.4	57.3	62.6	66.5	65.6	58.3	50.6	41.2	32.3	48.6

[1] Three-year average.

It is to be noticed that, almost without exception, both monthly and annual means of the Ellijay slope stations are higher than those of the base due to what are generally known as "inversions" of temperature. Doubtless readers of the REVIEW are fully cognizant of the significance of this term, but in the interest of those who may be less familiar with the subject, the following is offered:

Many observations on mountains and in balloons have shown that on the average, the temperature of the free air, when dry, diminishes about 1° F. for every 300 feet of increase in elevation. There are, however, many exceptions to this rule, as when the air instead of growing colder with increasing elevation actually becomes warmer up to a certain level, and then grows colder. This phenomenon is known as an "inversion" and the rate of warming with increase in altitude or cooling, as the case may be, gives what is known as the vertical temperature gradient. English meteorologists have recently come to use the term "lapse-rate" or "lapse" line to indicate the change of temperature with height.

The explanation of temperature inversions is found in an analysis of the relations which exist between the temperature, the pressure, and the volume of the atmosphere considered as a gas. Since the atmosphere is unconfined and subject to the perturbations introduced by the changing solar heat, diversified terrain, the presence or absence of large bodies of water and other causes, it is difficult to present a clear picture of the conditions which produce the warming and cooling of the air within a valley or upon a plateau. In general, it may be said that the atmosphere gets colder with elevation owing to its transparency to solar radiation; it is heated mainly at the bottom, or at the surface of the earth and because at ordinary temperature it emits more radiation than it absorbs.

For practical purposes one is not so much concerned with an explanation of the phenomenon as with the fact of its occurrence more frequently at one time and place than at another.

Returning now to a consideration of the mean minimum temperatures on the Ellijay slope, as well as those of other slopes in the investigated region, as found in Table 1, it is apparent that there is a pronounced seasonal influence on the several slopes, particularly on those characterized by temperature inversions. On all of these the months of April, May, October, and November show the greatest average difference between base and summit. Blantyre, Blowing Rock, Bryson, Cane River, Ellijay, Globe, Gorge, Hendersonville, and Transon are examples of marked differences between base and summit, the latter being the warmer.

A second point of interest in the figures of Table 1 is the fact that on the slopes of Altapass, Blowing Rock, Highlands, and in less degree Tryon, the minimum temperature at the base station, on the average, is *higher* than that on the summit or the reverse of the conditions that prevail at the other slopes. The explanations for these abnormal showings are given in full by Professor Cox; I can refer to only the most important in this review. At Altapass the base station lacks some of the characteristics of a true base station; at Blowing Rock the topography is the controlling factor; at Highlands the stations are located in two orchards, the Satulah and the Waldheim, the former, in which the base station is situated, is on a south slope and warm for its altitude.

In order to ascertain the frequency with which inversions occur on the Ellijay slope, I have tabulated, and present in Table 2 below, the individual differences between the base and slope stations for four different months, first, May, 1914, a month of frequent and, in some cases, large inversions; (2) November, 1914, a

month of the same character, but in a different season; (3) January, 1916, a winter month, and (4) July, 1915, as representing a summer month. The figures in the columns headed "base" are the minimum temperatures at the base station, the figures in remaining columns are the differences between the readings at the base and at the slope stations above, absence of sign indicates higher temperatures and the minus sign, lower.

TABLE 2.—*Temperature differences between base and slope stations on Ellijay Slope for the months and days as shown.*

[Figures without sign indicate the amount the slope station is above the base; minus signs, below.]

Date.	May, 1914, many large inversions.					November, 1914, many large inversions.					January, 1916, typical winter inversions.					July, 1915, typical summer inversions.				
	Base.	No. 2.	No. 3.	No. 4.	No. 5.	Base.	No. 2.	No. 3.	No. 4.	No. 5.	Base.	No. 2.	No. 3.	No. 4.	No. 5.	Base.	No. 2.	No. 3.	No. 4.	No. 5.
1	40	1	3	6	7	26	6	9	17	18	44	0	−3	−1	−3	56	2	2	3	1
2	37	2	7	9	8	29	6	13	18	16	54	3	1	3	−1	56	1	−1	0	−1
3	41	4	8	9	9	33	5	10	15	16	31	4	5	7	6	55	3	3	5	3
4	54	1	2	1	0	35	7	12	18	15	20	6	9	6	9	59	2	1	1	0
5	59	−1	−2	−5	−6	33	7	15	17	13	28	5	6	10	8	61	2	−1	−2	−3
6	48	5	9	8	5	27	6	12	18	18	48	−1	−1	0	−4	47	4	4	5	5
7	45	2	5	8	8	30	8	13	20	23	49	−1	0	−2	−5	51	5	5	7	5
8	47	0	0	6	6	40	7	10	9	9	35	1	−3	−2	−3	61	4	4	4	2
9	45	−3	−4	−6	−7	35	0	0	0	−1	29	−2	−5	−4	−2	54	5	4	7	7
10	35	2	6	9	11	22	0	3	6	5	28	2	1	2	0	59	3	1	2	1
11	44	5	10	15	13	25	5	10	13	14	48	1	0	1	−3	58	3	2	2	1
12	49	6	9	13	10	25	5	8	17	18	53	2	1	0	−4	61	5	6	6	3
13	54	0	3	5	3	34	4	6	9	9	45	−2	−5	−6	−8	61	4	3	4	2
14	45	3	3	2	5	37	2	9	11	11	23	0	−3	−5	−2	56	4	4	6	6
15	39	1	4	5	2	51	−2	0	−1	0	25	1	1	−2	−3	60	2	1	3	3
16	39	3	7	9	6	42	−2	−7	−5	−7	33	−2	−3	−4	−6	59	4	3	5	6
17	42	4	6	10	8	15	−1	−1	0	−2	15	−2	−5	−7	−10	58	5	6	8	5
18	49	2	2	2	−1	14	1	5	7	6	8	−1	−3	−1	0	58	4	4	7	5
19	34	6	12	11	11	22	0	3	4	3	10	2	0	3	5	60	4	3	6	6
20	35	4	9	15	15	7	−3	−3	−6	−7	22	3	2	4	5	60	3	3	6	4
21	36	6	11	17	18	10	−2	0	3	4	33	6	10	12	9	55	4	3	5	5
22	41	5	10	15	16	21	7	10	8	9	51	−1	−3	−3	−8	50	3	3	4	2
23	44	5	9	16	12	17	6	9	11	11	29	3	3	6	6	48	2	2	5	4
24	49	4	7	13	13	16	5	10	14	15	24	5	6	9	8	51	3	3	5	4
25	49	6	10	13	10	19	5	10	18	21	35	4	4	6	7	53	3	4	6	5
26	46	4	9	12	13	26	5	8	14	18	49	1	−1	0	−2	56	2	2	5	4
27	54	1	5	7	8	30	5	9	14	16	51	1	−1	−1	−3	57	1	2	3	3
28	50	2	6	9	13	35	4	10	9	5	49	4	3	3	0	59	1	2	7	6
29	50	5	10	16	18	48	−3	−6	−6	−6	51	2	1	2	−1	60	1	4	6	3
30	56	2	5	8	9	54	−2	−4	−4	−6	53	0	−3	−3	−6	60	2	3	8	5
31	55	2	6	10	11						56	−1	−4	−6	−9	61	1	3	7	8
Means	45.5	3.0	6.0	8.3	8.2	28.6	3.0	6.1	8.7	8.8	36.4	1.4	0.3	0.9	−0.6	56.8	3.0	2.8	4.7	3.6

INVERSIONS.

Frequency.—In the above table the impressive facts are the almost complete reversal of the usual rule of a decrease in temperature with increase of altitude during both May and November, 1914; a diminution in the amplitude of the variations in winter as exhibited by the record for January, 1916; and the tendency in that month for the natural rule to obtain at the highest station at which the mean minimum was 0.6° lower than at the base station, and finally, the rather regular occurrence of small and, perhaps, unimportant variations in summer as shown by the record of July, 1915.

When the observations of the four-year period are combined into a general mean, the results as shown in the graph Figure 3 appear. This figure gives the average monthly frequency, intensity, and the extreme range of inversions. It may be remarked in connection therewith, that on all the slopes May and November are the months of the greatest frequency and August of the least. The intensity of inversions, however, appears to be greatest in November with a second maximum in April. The extremes are found on the Tryon slope where winter inversions are of greater magnitude than those of spring. It is further remarked that the largest number of inversions noted on all of the six long slopes in any one year was 860, in 1913, and that the largest number on a single slope for the four-year period was 743 on Ellijay. Inversions occur on the short slopes with about as great frequency as on the long slopes.

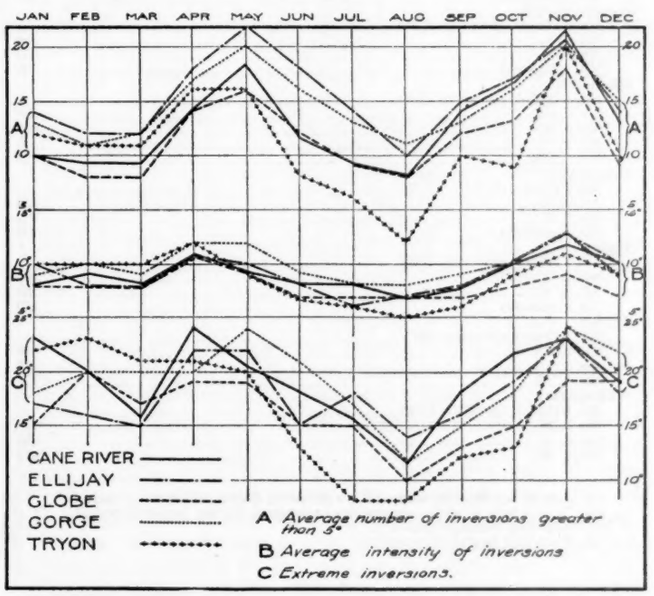


FIG. 3.—Monthly frequency, average, and extreme degrees of inversion on five selected long slopes.

TABLE 3.—*Length of growing season.*

Principal and slope station; elevation of base stations above mean sea level.	Height of slope stations above base (feet).	a	b	c	d	e	f	g	h	i
Altapass:										
No. 1 (base) elevation 2,230		Apr. 10	Oct. 2	Apr. 8	Oct. 15	Apr. 4	Oct. 28	201	175	190
No. 2, SE	250	Apr. 21	Oct. 9	Apr. 12	Oct. 26	...do....	Nov. 15	219	188	197
No. 3, SE	500	...do....	Oct. 10	...do....	Oct. 20	...do....	Oct. 27	195	189	191
No. 4, SE	750	...do....	Oct. 9	Apr. 16	Oct. 25	...do....	Nov. 15	219	175	192
No. 5, summit	1,000	Apr. 27	...do....	...do....	Oct. 19	...do....	Oct. 27	194	174	186
Asheville:										
No. 1 (base) elevation 2,445		Apr. 21	Oct. 2	Apr. 14	Oct. 15	Apr. 10	...do....	200	175	184
No. 2, N	155	Apr. 28	Oct. 9	Apr. 16	Oct. 20	Apr. 4	...do....	195	176	187
No. 2a, S	155	...do....	...do....	...do....	...do....	...do....	...do....	195	176	187
No. 3, N	380	...do....	...do....	...do....	...do....	...do....	...do....	193	176	187
No. 3a, S	380	...do....	...do....	...do....	...do....	...do....	...do....	195	176	187
Blantyre:										
No. 1 (base) elevation 2,090		May 20	Sept. 22	Apr. 30	Oct. 8	Apr. 19	Oct. 28	173	153	161
No. 2, NW	300	Apr. 21	...do....	Apr. 16	Oct. 7	Apr. 10	Oct. 27	189	154	174
No. 3, NW	450	...do....	Oct. 9	Apr. 12	Oct. 17	Apr. 4	...do....	190	185	188
No. 4, NW	600	...do....	...do....	...do....	Oct. 20	...do....	...do....	194	188	191
Blowing Rock:										
No. 1 (base) elevation 3,130		May 11	Oct. 1	Apr. 22	Oct. 14	Apr. 10	...do....	189	162	175
No. 2, S	450	...do....	Oct. 9	...do....	Oct. 17	...do....	...do....	189	162	178
No. 3, SE. (base)	450	May 20	Sept. 20	May 5	Sept. 23	Apr. 18	Sept. 27	158	130	141
No. 4, SE	625	May 11	Sept. 22	Apr. 26	Oct. 7	Apr. 15	Oct. 27	189	134	164
No. 5, SE	800	...do....	...do....	...do....	...do....	...do....	...do....	189	134	164
Bryson:										
No. 1 (base) elevation 1,800		May 12	Sept. 22	Apr. 28	Oct. 8	Apr. 19	Oct. 28	190	133	163
No. 2, N	385	Apr. 21	Oct. 2	Apr. 11	Oct. 13	Mar. 29	...do....	199	175	185
No. 2a, S	385	Apr. 28	...do....	Apr. 16	...do....	...do....	...do....	199	157	180
No. 3, summit	570	Apr. 21	Oct. 9	Apr. 8	Oct. 20	Mar. 28	...do....	206	188	195
Cane River:										
No. 1 (base) elevation 2,650		May 20	Sept. 23	May 5	Oct. 6	Apr. 19	Oct. 27	173	134	154
No. 2, N	190	May 11	Oct. 2	Apr. 22	Oct. 14	Apr. 11	...do....	189	162	175
No. 3, NE	400	Apr. 29	...do....	Apr. 19	...do....	...do....	...do....	189	174	178
No. 4, summit	1,100	...do....	Sept. 30	Apr. 22	...do....	Apr. 13	...do....	189	156	175
Ellijay:										
No. 1 (base) elevation 2,240		Apr. 28	Sept. 22	Apr. 24	Oct. 8	Apr. 18	Oct. 28	190	148	166
No. 2, N	310	Apr. 21	...do....	Apr. 10	...do....	Apr. 6	...do....	190	169	181
No. 3, N	620	...do....	Oct. 9	Apr. 12	Oct. 19	Apr. 4	Oct. 27	193	188	190
No. 4, N	1,240	Apr. 28	...do....	Apr. 16	...do....	...do....	...do....	194	175	186
No. 5, summit	1,760	Apr. 27	...do....	Apr. 17	...do....	...do....	...do....	189	177	185
Globe:										
No. 1 (base) elevation 1,625		Apr. 22	Oct. 10	Apr. 17	Oct. 20	Apr. 10	Oct. 28	195	178	186
No. 2, E	300	Apr. 11	...do....	Apr. 6	Oct. 26	Mar. 28	Nov. 15	219	189	203
No. 3, summit	1,000	Apr. 21	...do....	Apr. 8	Oct. 20	...do....	Oct. 27	207	188	195
Gorge:										
No 1 (base), elevation 1,400		May 12	Oct. 2	Apr. 27	Oct. 16	Apr. 16	Oct. 28	190	157	172
No. 2, N. E	290	May 11	...do....	Apr. 22	Oct. 15	Apr. 10	...do....	190	163	176
No. 3, S	615	...do....	...do....	Apr. 19	...do....	Apr. 4	...do....	190	163	179
No. 4, N. (old)	840	Apr. 21	Oct. 10	Apr. 8	Oct. 26	Mar. 29	Nov 15	219	189	201
No. 4, NE. (new)	840	...do....	...do....	...do....	...do....	Mar. 28	Nov. 16	220	189	201
No. 5, summit	1,040	...do....	...do....	...do....	...do....	...do....	...do....	220	189	201
Hendersonville:										
No. 1 (base), elevation 2,200		Apr. 30	Sept. 22	Apr. 23	Oct. 8	Apr. 19	Oct. 28	190	153	168
No. 2, E	450	Apr. 28	...do....	Apr. 22	...do....	Apr. 14	Oct. 27	189	147	169
No. 3, E	600	...do....	...do....	Apr. 16	Oct. 12	Apr. 4	...do....	194	147	179
No. 4, summit	750	...do....	Oct. 9	...do....	Oct. 20	...do....	...do....	194	176	187
Highlands:										
No. 1 (base), elevation 3,350		...do....	Oct. 10	...do....	...do....	...do....	...do....	194	175	187
No. 2, SE	200	...do....	Sept. 22	...do....	Oct. 12	...do....	...do....	193	147	179
No. 3, SE	325	June 14	Sept. 21	May 29	Sept. 23	May 10	Sept. 26	135	100	117
No. 4, SE	525	Apr. 29	Sept. 22	Apr. 20	Oct. 3	Apr. 5	Oct. 27	189	146	166
No. 5, SE	725	...do....	...do....	Apr. 22	Oct. 7	Apr. 13	...do....	189	146	168
Mount Airy:										
No. 1 (base), elevation 1,340		Apr. 21	Oct. 10	Apr. 11	Oct. 18	Apr. 4	Oct. 28	201	184	190
No. 2, W	160	Apr. 10	...do....	Apr. 4	Oct. 26	Mar. 28	Nov. 15	219	189	205
No. 3, E	160	Apr. 21	...do....	Apr. 11	...do....	Apr. 4	...do....	219	184	198
No. 4, summit	360	Apr. 10	...do....	Apr. 8	...do....	Apr. 5	...do....	219	189	201
Transon:										
No. 1 (base), elevation 2,970		June 11	Sept. 20	May 17	Sept. 23	Apr 18	Sept. 27	158	103	129
No. 2, W	150	May 11	Oct. 2	Apr. 22	Oct. 14	Apr. 11	Oct. 27	189	162	175
No. 3, W	300	...do....	Oct. 1	...do....	...do....	Apr. 10	...do....	189	162	175
No. 4, summit	450	...do....	Oct. 9	Apr. 19	Oct. 17	Apr. 4	...do....	189	162	181
Tryon:										
No. 1 (base), elevation 950		Apr. 27	Oct. 21	Apr. 16	Nov. 2	Apr. 5	Nov. 16	213	182	200
No. 2, SE	380	Apr. 10	...do....	Mar. 30	Nov. 8	Mar. 23	...do....	232	207	223
No. 3, SE	570	...do....	...do....	...do....	Nov. 5	...do....	Nov. 15	226	207	220
No. 4, SE	1,110	...do....	Oct. 9	Apr. 6	Oct. 20	Mar. 28	Oct. 28	207	188	197
Wilkesboro:										
No. 1 (base), elevation 1,240		Apr. 22	Oct. 11	Apr. 15	Oct. 18	Apr. 11	...do....	200	177	186
No. 2, N	150	Apr. 11	Oct. 10	Apr. 6	Oct. 24	Mar. 29	Nov. 8	212	189	203
No. 3, N	350	Apr. 10	...do....	...do....	Oct. 26	...do....	Nov. 15	219	189	203
No. 4, W	430	...do....	Oct. 20	...do....	Nov. 5	...do....	Nov. 16	226	201	211

(a) Date of last freezing temperature in spring during four-year period.
(b) Date of first freezing temperature in autumn during four-year period.
(c) Four-year average date of (a).
(d) Four-year average date of (b).
(e) Earliest date of last freezing temperature in spring during four-year period.
(f) Latest date of first freezing in autumn during four-year period.
(g) Length in days of longest growing season, or interval between (a) and (b) of same year.
(h) Length in days of shortest growing season, or interval between (a) and (b) of same year.
(i) Average length of growing season, or interval between (c) and (d).

TOP FREEZES AND NORMS.

Under the above caption Professor Cox discusses those cases where cold north and northwest winds in the rear of cyclones sweep over the terrain, bringing low temperature alike to mountain top, slope and valley below. These winds are characteristically cold and blow with sufficient force to displace any warm air that may still linger on the valley floor. The pressure gradient upon which these winds depend is greatest, of course, in winter

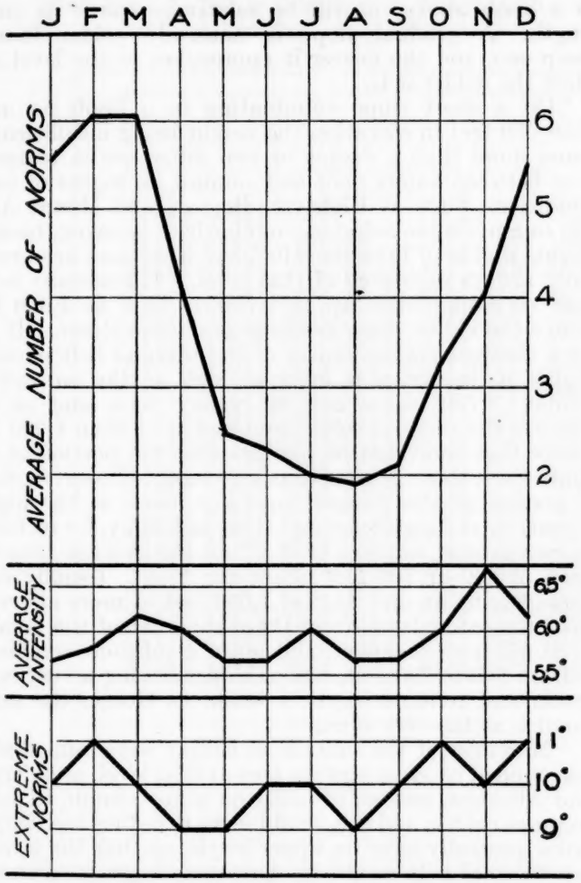


FIG. 4.—Monthly frequency and average and extreme degrees of norm on six long slopes.

and naturally the incursions of cold air are most frequent in that season. The average distribution throughout the year is shown in Figure 4.

HOUR-DEGREES OF FROST (HF°)

Hour-degrees of frost is the term used to express the duration of temperatures below 32°. The numbers are obtained by measuring with a planimeter the area on the thermograph trace sheets between the 32° line of the sheet and the course of the curve when it passed below that line. The author presents two graphs—Figures 5 and 6—which illustrate graphically the number of HF° at the stations on the various slopes. Figure 5 shows that the largest number of HF°, for 10 selected inversions, was 173 at station No. 3 in the Waldheim orchard —a station in a frost pocket in that orchard.

AUTHOR'S CONCLUSION.

"It should be apparent from the data presented in the discussion that minimum temperature and its duration are the chief factors involved in the growing of fruit in the North Carolina mountain region, just as they are in any other orchard region, provided, of course, sufficient moisture is supplied through rainfall or irrigation.

"However, maximum temperature is often a consideration. It has been shown that the maxima are much higher in the winter on a southerly than on a northerly slope and in all seasons of the year higher on a westerly than on an easterly slope. But relatively high maximum temperatures are not always to be desired. Where the maximum is abnormally high in the winter and spring, so as to force the buds prematurely, there is danger of damage from ensuing frosts or freezes, sometimes in contrast with slopes where the maximum does not rise so high. In any case, shade must be avoided such as noted in the upper portions of the orchards at both Asheville and Cane River, because it not only prevents necessary sunlight, but also serves to reduce the sensible temperature after precipitation to a lower point

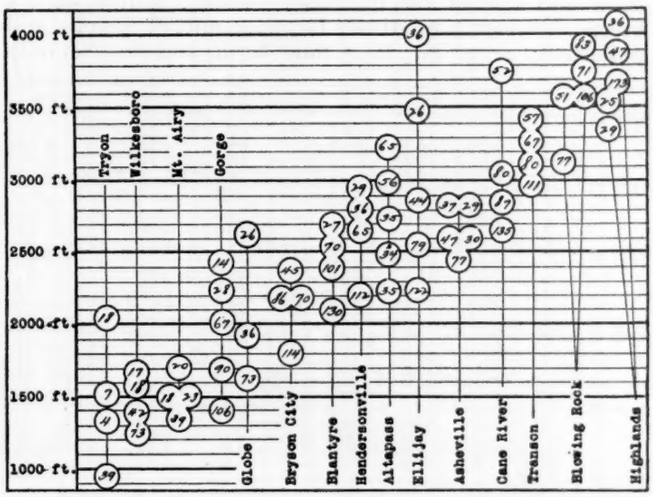


FIG. 5.—Average number of hour-degrees of frost, 10 selected inversions.

than that shown by the thermometer through the retention of the moisture on the vegetation and fruit.

"So far as the minima are concerned, it is obvious that great care should be taken in the selection of a site for an orchard. Valley floors must in nearly all cases be avoided. There the temperature on critical nights of inversion often falls 15° or 20°, and sometimes even 25° or 30°, lower than higher up on the slope.

"Some valley floors are, moreover, colder than others. Wide floors, such as those at Blantyre and Bryson, surrounded by high mountains at some little distance, where the loss of heat through radiation is quite rapid, are somewhat colder than other floors closely shut in, such as at Ellijay. The latter is not, indeed, warm, but its slightly higher minima as compared with Blantyre and Bryson are due to obstructed radiation, although the area of radiating surface in the immediate vicinity of the closed-in floor is unusually large, but not sufficient to offset the obstruction referred to by raising the sky line.

"Valley floors similar to those at Tryon and in the Flat Top orchard at Blowing Rock have been shown to be warm on certain nights of inversion considering their elevation above sea level, both relatively warmer than Ellijay, and this, too, in spite of the fact that the floor at Tryon, especially, is wide. However, the higher average minima at Tryon, as well as Blowing Rock, are due to the prevalence of the nocturnal mountain breeze down

the slope and valley from the great surface area around the summer station. During nights of inversion, when conditions are not favorable for the mountain breeze, the temperature falls at these two places comparatively low.

"While the great area above is responsible for the nocturnal breeze and the raising of the minima on the floor, it, at the same time, causes low temperature at the higher levels, because of the large area of radiating surface in proportion to the air available for interchange, so that on such slopes as these two, as well as at Altapass, the upper levels are cold and the valley floors often comparatively warm.

"This research has shown that the mountain breeze does not develop at night and flow down a valley unless there is great surface area around the summit station. On no valley floor where the slopes culminate in knobs has the nocturnal breeze been noted. The thermograph traces on the floors at Bryson, Blantyre, Ellijay, Gorge, Cane River, and Mount Airy, all with small mass, never show any sign of the mountain breeze. Before such a breeze develops a relatively large amount of heavier and potentially colder air above must form, and this can only

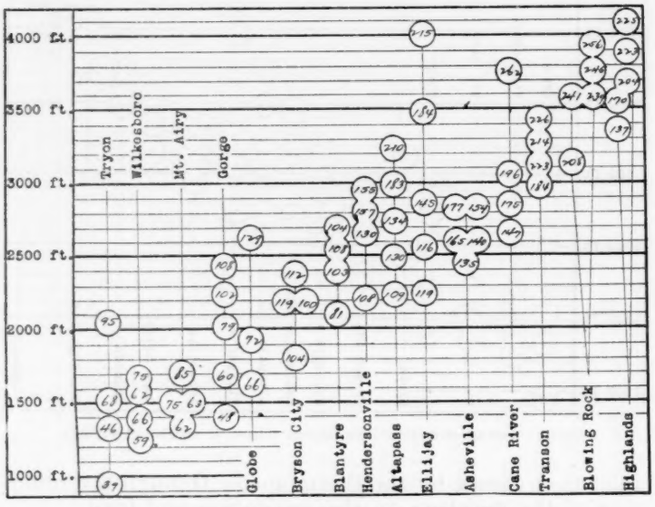


FIG. 6.—Average number hour-degrees of frost, 10 selected norms.

develop over a plateau-like surface. There is no opportunity for such development over a knob. Where the highest points are mere peaks or knobs, they partake of the temperature of the free air surrounding and are always relatively warm on nights of inversion, and this, too, in spite of the fact that a knob is best situated topographically for loss of heat through radiation, as its angle of free radiation may exceed even 180°.

"The descending nocturnal breeze may properly be compared with a waterlike flow as it passes down the slope and mixes with the cold air of the valley floor, and it is entirely unlike the slow exchange of free air over a valley with that resting on a slope. The cold air sometimes collects on benches or coves on a slope, and when great difference in density exists between it and the neighboring free air the cold air slips off and passes down the slope, immediately giving place in turn to warmer air. Such a phenomenon has often been observed at Blantyre on the descending slope near the base of little Fodderstack.

"Coves and even shelves or benches on slopes should be avoided so far as practicable in the planting of fruit trees because of the low night minima, making possible the formation of frost there, while other portions of the slope entirely escape.

"Many topographical conditions are involved in their effect upon the minima on a slope. Generally speaking, the steeper the slope the warmer it is during nights of inversion. At the same time, if there is a steep slope directly opposite and close by, making the valley deep and narrow, the entire slope will be relatively cold, rather than warm, up to the level where the free air becomes practically limitless, although, as already stated, its base may be warmer than a wide valley floor. If this steep slope has no opposing slope and it culminates in a knob above, it will be relatively warm its entire length. A gradual slope is naturally colder than a steep one, and the nearer it approaches to the level of a plain the colder it is.

"On a short slope culminating in a knob no more than 500 feet in elevation the height being insufficient to cause more than a degree or two difference in temperature between valley floor and summit on nights of norm conditions, such as Blantyre, Bryson, and Mount Airy, the summit is the safest section for fruit growing, because during nights of inversion the highest minima are practically always registered at that level. This usually is the case on slopes even up to levels as high as 1,000 feet above the valley floor, as Gorge and Cane River. It has been shown that the center of the thermal belt on some nights of inversion is even as high as the summit of Ellijay, 1,760 feet above the valley floor, and on the average the thermal belt is centered more than 1,200 feet above that floor, due to the fact that the portion of the slope lower down is comparatively cold. However, there is always greater danger from top freeze at the higher elevations of long slopes, and these at Ellijay, for instance, have a greater number of H F° on the average than the level of 600 or 700 feet above the floor. Usually on a slope having an elevation of 1,000 feet or more above its floor the safest level, from the standpoint of the number of H F° from inversion and norm conditions combined, is from 300 to 700 feet, but on slopes having a very small grade and terminating in a knob, as Gorge, the safest point is at the very summit.

"Moreover, if the summit at Ellijay were immediately surrounded by great surface area at that level, as at Tryon and Altapass, instead of being on a mere knob, it would be much colder, and this would serve to reduce the temperature generally over its upper levels, so that the level of the thermal belt would be correspondingly lowered and its width reduced to very small limits. Such a slope would indeed be a cold one practically from base to summit, if there were high opposing slopes close by.

"While the slopes at Bryson and Blantyre are warm as compared with their respective floors during nights of inversion, they are, nevertheless, relatively cold for their elevation, because they are located in vast frost pockets formed by surrounding mountains which tower above at considerable elevation. Frost pockets must be avoided as far as practicable, whether large or small. The one in the Waldheim orchard at Highlands, a small depression or sink, although much unlike those at Bryson and Blantyre, is nevertheless equally objectionable.

"An ideal slope for fruit growing is one of moderate elevation above sea level, the basic altitude varying, of course, in different portions of the country, fairly steep and culminating in a knob with no surrounding mountains, or if any, at least, situated so far distant as to have no effect upon the temperature conditions of the slopes involved, such as Mount Airy and Wilkesboro, or the lower levels of a slope such as Tryon, which is warm because of the absence of opposing slope and because of the influence of the nocturnal breeze, although its upper

levels are cold on account of the great area surrounding the summit.

"The subject of vegetation must be considered, dense vegetation being responsible for great loss of heat through radiation, and a cultivated orchard is therefore warmer than one planted in grass.

"The data presented in this study make plain the necessity for great care in the selection of a property for the purpose of fruit growing. The topography of a region is paramount. Frost pockets should be avoided and valley floors of all kinds as far as practicable, unless means are available for orchard heating. The altitude above sea level is in every case a consideration and, in a degree, the elevation above the valley floor.

"All these questions must be given careful consideration and the effect of one upon another weighed in the balance. No hard and fast rule can be made in the determination, as the factors involved are so many and so complicated that each site must be considered by itself."

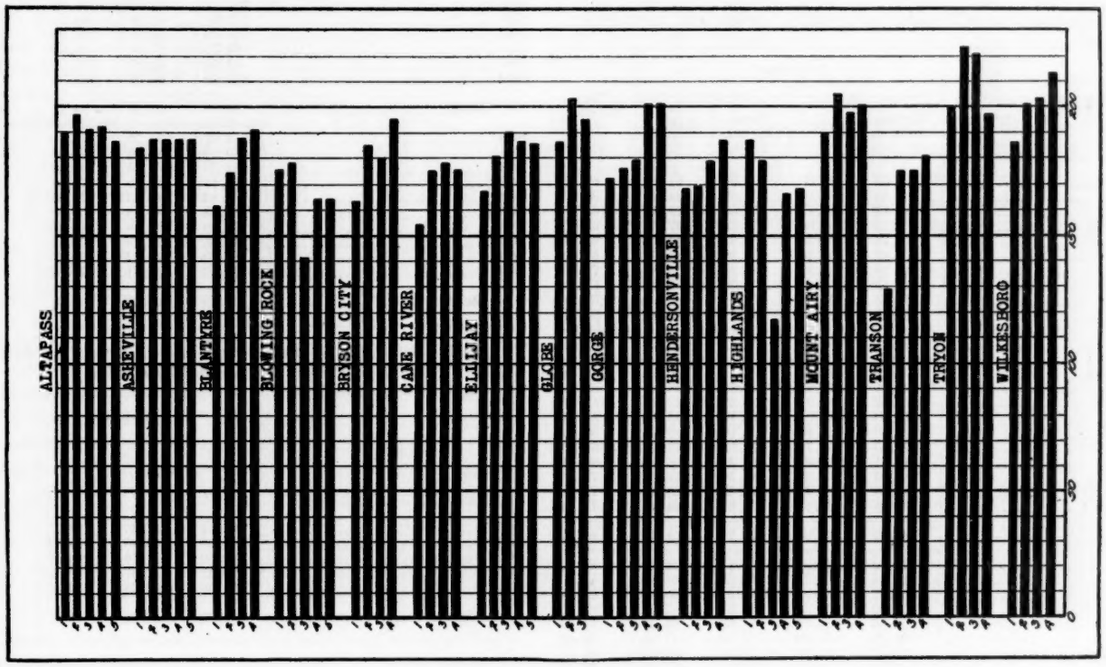


FIG. 7.—Length of growing season.

THE RAINFALL OF JAMAICA.[1]

Under the above title is presented the third report on the rainfall of Jamaica by the same author, bringing the statistics down to the end of 1919. Unfortunately, the author did not live to see the completion of his work, but his daughter, Miss C. Maxwell Hall, with the aid of Mr. J. F. Brennan, Government meteorologist, has faithfully carried the work to a conclusion. The first part of the work is devoted to presenting the monthly and annual averages for a total of about 250 stations well scattered over the island. The latter is divided into five unequal portions, viz, Northeast, Central, West Central, North, and South. The three subdivisions first named form a somewhat irregularly shaped zone extending almost entirely across the island from east to west, and it contains the most elevated parts. The average elevation of the stations in the Northeast is 1,375 feet, and that subdivision has naturally the greatest rainfall; the next subdivision in point of elevation is the West Central, with 960 feet, and finally the coastal regions of both the north and the south of the island have an elevation of 472 and 490 feet, respectively.

The 50-year monthly means for the island as a whole are presented in Table 1 below.

In Table 2 will be found the annual amounts for each of the five principal subdivisions and for each year of the period 1870–1919. These data will serve as valuable material in the study of the secular variation of rainfall in the Tropics.

[1] The rainfall of Jamaica from about 1870 to 1919, by Maxwell Hall, M. A., F. Roy. Met. Soc., Government meteorologist.

50612—23——3

TABLE 1.—*Mean monthly rainfall, Jamaica, 1870–1919 (inches and hundredths).*

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
1870–1879	4.46	2.38	3.34	3.25	9.05	4.74	4.31	6.66	6.85	10.07	6.71	5.59	67.41
1880–1889	3.78	2.51	2.49	4.18	9.07	7.77	4.32	6.83	6.87	8.04	5.08	5.60	66.54
1890–1899	3.13	2.97	2.75	5.17	10.56	5.81	5.64	6.35	7.64	13.01	7.71	5.41	76.15
1900–1909	4.27	3.30	3.96	4.59	7.93	9.73	4.76	6.84	8.28	10.15	8.09	5.08	76.98
1910–1919	4.04	2.75	3.54	6.03	9.12	5.61	4.70	7.42	8.26	9.51	10.60	5.61	77.19
Mean, 50 years	3.94	2.78	3.22	4.64	9.15	6.73	4.75	6.82	7.58	10.15	7.64	5.46	72.86

TABLE 2.—*Annual rainfall tables, 1870–1919 (inches and hundredths).*

Year.	Divisions.				The island.
	Northeast.	North.	West Central.	South.	
1870	110.60	83.09	102.98	61.07	89.43
1871	69.45	41.88	54.56	34.46	50.09
1872	59.42	40.79	51.50	29.02	45.18
1873	84.12	52.64	67.79	47.71	63.06
1874	97.18	68.25	62.97	47.35	68.94
1875	71.89	47.15	56.16	34.47	52.42
1876	90.38	54.71	87.33	52.99	71.35
1877	100.72	56.53	64.06	52.27	68.40
1878	104.12	62.99	72.44	66.11	76.42
1879	122.55	65.44	87.54	79.85	88.84
Mean	91.04	57.35	70.73	50.53	67.41
1880	76.37	47.01	64.91	33.47	55.44
1881	91.24	49.42	75.32	58.42	68.60
1882	65.48	43.76	78.59	43.67	57.87
1883	72.30	41.52	78.19	45.02	59.26
1884	69.00	41.87	73.10	43.63	56.90
1885	70.55	52.77	72.62	43.52	59.86
1886	126.61	60.98	88.21	86.64	90.61
1887	80.25	61.07	80.14	61.16	70.66
1888	98.00	54.42	70.43	65.58	72.11
1889	99.81	56.82	75.91	64.02	74.15
Mean	84.96	50.96	75.74	54.51	66.54
1890	75.09	48.29	89.91	44.41	64.42
1891	110.56	66.71	100.50	61.03	84.70
1892	101.55	58.10	82.05	50.29	73.00
1893	106.50	63.17	108.66	67.65	86.49
1894	90.56	54.04	95.93	61.01	75.39
1895	97.38	56.35	85.38	47.36	71.62
1896	95.42	54.90	78.31	45.79	68.61
1897	93.95	58.25	95.46	62.67	77.59

TABLE 2.—*Annual rainfall tables, 1870–1919 (inches and hundredths)*—Continued.

Year.	Divisions.				The island.
	Northeast.	North.	West Central.	South.	
1898	102.92	52.44	84.26	55.67	73.82
1899	112.10	61.31	101.28	68.62	85.82
Mean	98.60	57.36	92.17	56.45	76.15
1900	96.91	50.67	79.84	51.15	69.65
1901	107.88	64.18	87.31	64.50	80.96
1902	95.97	58.78	89.75	49.14	73.37
1903	88.46	51.05	82.83	51.17	68.38
1904	112.12	63.72	104.40	72.35	88.15
1905	112.91	61.33	94.23	72.31	85.20
1906	109.69	56.25	100.90	79.96	86.71
1907	64.72	37.80	64.53	43.32	52.61
1908	93.56	63.87	86.29	54.78	74.62
1909	112.66	66.03	101.84	80.12	90.16
Mean	99.48	57.37	89.21	61.90	76.98
1910	119.07	64.25	93.08	54.66	82.76
1911	80.30	46.53	78.80	37.99	69.90
1912	101.38	64.26	93.29	46.15	76.26
1913	87.19	51.09	77.08	41.95	64.34
1914	68.86	43.53	78.88	38.19	57.36
1915	152.93	88.39	103.60	74.88	104.95
1916	148.80	85.38	110.45	80.46	106.32
1917	110.65	61.28	99.18	52.62	80.93
1918	87.70	46.42	92.45	49.11	68.92
1919	98.12	51.71	73.32	54.72	69.45
Mean	105.50	60.28	90.01	53.07	77.21

TABLE 3.—*Summary of annual rainfall, Jamaica, by subdivisions and decades (inches and hundredths).*

Year.	Divisions.				The island.
	Northeast.	North.	West-central.	South.	
1870–79	91.04	57.35	70.73	50.53	67.41
1880–89	84.96	50.96	75.74	54.51	66.54
1890–99	98.60	57.36	92.17	56.45	76.15
1900–09	99.48	57.37	89.21	61.90	76.98
1910–19	105.50	60.28	90.01	53.07	77.19
Mean	95.92	56.66	83.57	55.29	72.86

—*A. J. H.*

NOTES, ABSTRACTS, AND REVIEWS.

TORNADO NEAR WASHINGTON, D. C.

A true tornado apparently originating between 2:30 and 3:00 p. m. April 5, 1923, in the northern portion of Rock Creek Park, Washington, D. C., about 5 miles from the United States Capitol, moved thence northeastward, crossing the Baltimore and Ohio Railroad tracks about a quarter-mile north of the Silver Spring station, Md., and continued thence north-northeast for about 11 miles. Its path was from 100 to 250 yards in width; a funnel-shaped cloud was seen by some observers. Four persons were seriously injured, seven houses were demolished, and about a dozen more suffered some damage. The property loss is estimated at $100,000.

At the time this storm occurred a vigorous cyclone was moving northeastward, with its center probably between 200 and 300 miles distant, in a northwesterly direction. The morning map (8:00 a. m.) showed the center in southern Ohio, the sea-level pressure near the center being about 29.58 inches; the evening chart of the day (8:00 p. m.) located the center in the north central part of New York, with pressure about 29.46 inches. The trace of the siphon barograph at the Washington office shows a rapid fall in pressure and an even more rapid rise about the time the storm occurred, the marked dip and rise covering about 45 minutes. The trace indicates 29.43 inches at 2:00 p. m., lowest, 29.34, about 2:35, and return to 29.42 by 2:45 and to 29.45 by 2:55 (all being station pressures—reduction to sea-level, about +0.12).

The thermograph trace shows a sharp fall of about 9° (72° to 63°) about the time the tornado formed. The wind, from south-southeast, 12 to 16 miles per hour, during the period 2:00 to 2:40, shifted to west-northwest by 2:45, and at about 2:50 reached the highest velocity of the day, 30 miles. Light rain began at the Washington office 2:27 p. m., but became heavy only at 3:22, many minutes after the sharp pressure changes, the drop in temperature, and the shift in wind had occurred; in 12 minutes, ending 3:34, 0.13 inch fell, then the rain returned to light, and continued so till it ceased, at 8:10 p. m.—*H. C. H.*

TORNADO OF MARCH 3, 1923, NEAR ELWOOD, KANS.

A funnel-shaped cloud extending to the ground was observed on the north bank of the Missouri River, 1½ miles southwest of Elwood, Kans., at about 5:35 p. m., March 3, 1923. The tornado followed a straight course, moving east of northeast for a distance of about 4 miles. It was preceded by a light thunder shower and accompanied by heavy rain, which continued for only a few minutes. Its path in Kansas, about 2 miles in length, was mostly across alfalfa fields, 4 alfalfa barns were damaged, several smaller buildings blown down, 12 large apple trees uprooted, 1 small frame house demolished, and a semaphore, made of iron and bolted to a concrete base, located at the west end of the St. Joseph and Grand Island Railroad bridge, was blown across the railroad tracks. The estimated property damage was $4,000. No lives were lost and no one was injured.

The tornado crossed the Missouri River just north of the bridge and the first building in its path in Missouri was a sash and door factory, which was damaged to the extent of approximately $20,000. This was by far the heaviest single property loss. The tornado then passed over railroad yards for a distance of four blocks, causing no serious destruction, except to telephone and trolley lines, which were prostrated. After leaving the railroad yards its course for about a mile was through thickly settled business and residential districts. The tornado apparently rose and fell, as the destruction in its path was not continuous. The width of the destructive portions of the path varied from 100 to 200 feet. Fifty buildings were damaged more or less, the damage to tin and shingle roofs being especially noticeable. Few substantial buildings were seriously damaged. At the Weather Observatory, about three-fourths of a mile north of the nearest point in the path, the wind attained an extreme velocity of 60 miles an hour from the west at 5:40 p. m., and at that time the barometer reading was the lowest, 29.29 inches.[1] No one was killed and only nine persons were injured, most of the injuries being slight. The property damage in St. Joseph was estimated at $50,000.—*W. S. Belden.*

DOUBLE-WALLED WATERSPOUTS.

Double-walled waterspouts, or waterspouts within waterspouts, appear to be such a rare phenomenon that it seems worth while to reprint portions of several recent accounts and to add a description of a still later occurrence reported in a letter to the Marine Division of the Weather Bureau.

On June 30, 1922, Dr. G. D. Hale Carpenter, while on the shores of Lake Victoria Nyanza, Uganda, witnessed a double-walled waterspout which he describes in *Nature* [2] as follows:

> At daybreak on June 30 there were very lowering black clouds and every indication of an immediate heavy storm. While looking out from the tent, I suddenly saw that a waterspout was traveling obliquely toward us, and as it eventually came to within about 100 yards of the shore a very good view was obtained for about five minutes before it came to an end. * * *
>
> The pedicle was extremely narrow at its lower end, and not quite straight, being sinuous in outline. It broadened out gradually into a column which went up into the low cloud; the core of this column was much less dense than the periphery, and the violent upward spiral ascent of the water could be clearly seen. * * * Surrounding the central core, but separated from it by a clear narrow space, was a sheath, the lower end of which faded away some distance above the water. The profile of this sheath was undulating, it being thicker in some places than others.

In the same issue of *Nature*, commenting on Dr. Carpenter's description, Capt. D. Brunt says:

> The existence of an outer sheath, separated from the central core by a clear space, would appear to require a discontinuity of water content of the air, symmetrical about the axis of the whirl. It does not appear possible to explain it even as the effect of discontinuities of velocity with the whirl. No physical explanation of this clear space can be suggested.

Another instance of an apparent double-walled waterspout is also described in *Nature* [3] by Mr. H. E. Wood, of the Union Observatory, Johannesburg, who observed one on November 11, 1922. He says:

> The interesting feature of the waterspout seemed to me to be the detail of the earth-end: there was a well-marked "core" surrounded by a less dense sheath.

On September 1, 1922, Maj. W. C. Ball saw two cloud pendants at Clovelly Harbor on the southwest coast of England. The following description is taken from the Meteorological Magazine [4]:

> Both pendants were in the form of inverted cones, which depended from the well-defined and dense black under-surface of a cloud. In the case of one pendent, the cone continued in the form of a long tail similar to the lash of a whip. This tail extended about two-thirds of the way down to the sea and was bent into a curve, so that at its lower end it was almost horizontal. The edges of the tail were quite sharp and well defined * * * Below the lower end of the tail another portion was seen rising from the sea. "The part rising from the water was less distinct than the tail, which was very sharply defined; it appeared later and had a curious filmy appearance. * * * I judged that the spout might be about two miles from the shore, and that the part rising from the water was certainly higher than the mast of a fishing boat."

The latest account of the phenomenon in question is that furnished to the Marine Division of the Weather Bureau by the master of the Danish steamship *Hammershus*. It is quoted here practically in full:

> On March 7 of this year [1923] at 11 a. m., this vessel was in latitude 3° N. and longitude 29° 30′ W. on a voyage from Buenos Aires to Denmark.
>
> It had been raining very heavy all the previous night, and was still doing so. The wind was moderate but shifty. After a heavy rain-squall it cleared up so much that we could see about a mile, but it was still raining heavy. At 11 a. m. a remarkable phenomenon was observed.
>
> A ring of spray rising from one to three feet above the sea level and about two feet wide was passed by the vessel at a distance of about 20 fathoms from its eastern edge. The ring was about 150 feet in diameter. The spray had a rotating motion in the direction of the hands of the clock in the form of a nearly perfect circle. Now in the centre of this large ring, there was another much smaller ring with a radius of about 8 feet. This second ring also consisted of spray moving in the same direction as the outer ring. Apparently its motion was more violent and the spray also seemed to rise higher from the surface of the water.
>
> Between the two rings the sea had the same appearance as at the outside of the outer ring; you could see the rain pouring down. Inside the inner ring the sea was quite smooth. You could not see rain pouring down and the surface seemed to be concave. This may have been an illusion, though, resulting through the spray revolving round the edge of the ring. Both rings seemed to be absolutely concentric and travelled in a due westerly (true) direction at the rate of about 10 miles an hour. * * *.

—*H. L.*

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[1] The barograph trace for the interval during the passage of the tornado shows a V-shaped fall in pressure with about 0.05 inch vertical drop just before the apex of the V was reached. It will be remembered that barograph records available during the passage of tornadoes invariably show a very sudden fall in pressure, amounting in extreme cases to about a third of an inch. The recovery in pressure is immediate. This feature in the St. Joseph barograph is just barely perceptible.—EDITOR.

[2] *Nature*, London, Sept. 23, 1922, p. 414.

[3] *Nature*, London, Jan. 20, 1923, p. 82.

[4] *The Meteorological Magazine*, London, Oct., 1922, page 249.

FROZEN SOIL IN SPITZBERGEN.

By W. WERENSKIOLD.

[Excerpt from *Geofisiske Publ.*, vol. 2, No. 10, Kristiania, 1922.]

In regions with a sufficiently low mean annual temperature, combined with slight snowfall, the subsoil is constantly frozen. A layer of snow acts as a good insulator, and the ground is thus protected against excessive cooling in countries with heavy snowfall.

Spitzbergen affords the natural condition for a formation of permanent frozen subsoil. The mean annual temperature is about − 8° (Centigrade), and the snow that comes during the winter, is blown together in heaps, mostly in cirques and other hollows. The snow is also to a great extent blown out of the valleys and deposited on the fiord ice.

If the temperature is supposed to rise uniformly with one degree centigrade per 40 metres, the layer of frozen subsoil—earth and rock—should attain the enormous thickness of about three hundred metres, or one thousand feet. In the Swedish coal mine (Sveagruvan) in Lowe Sound a temperature of 0°C. was actually found in a depth of about 320 metres below the surface, and 430 metres from the mouth of the level adit. The rock is quite dry.

During the summer the soil thaws to a depth of some 2 feet, and the ground is constantly water-soaked. The frozen soil is a very important factor in all sort of ground work, diggings, and foundations. Frost-safe cellars do not exist in this country; and if the stability of a stone wall or pillar must be absolutely certain, it must be founded on solid rock. The chief difficulty seems to be that a concrete wall, for instance, acts as a better heat conductor than the water-soaked soil, and may therefore cause thawing at the bottom. If the foundation is sufficiently deep in the frozen soil—5 feet or so—there is generally no danger.

The frozen soil continues for some distance under the sea bottom; but the upper limit slopes down at a quicker rate than the beach, and disappears farther out under the sea.

The conditions are somewhat different at different places, chiefly owing to the variable temperature of the sea water, and the profile of the beach. At the pier of the Swedish mine, the ice was found to stretch under the sea bottom to a distance of about 100 metres from the shore, according to information gathered at the place.

THE PRÖTT THEOREM.[1]

By F. LINKE.

[Abstract reprinted from *Science Abstracts*, Apr. 25, 1923, p. 174, § 429.]

By his study of psychometric tables and graphic representations of the connection between temperature and humidity of the air, C. H. Prött was led to the discovery of laws which on account of their easy applicability merit the attention of meteorologists. He maintains that in many cases of technique and hygiene the temperature and relative humidity of the air do not sufficiently characterize the thermal state of moist air, and even lead to false conceptions. What is much more important is to determine the total thermal content of the air, consisting on the one hand of free heat as revealed in the atmospheric temperature, and on the other hand of the heat latent in the aqueous vapour. This total thermal content is, he maintains, solely indicated by the reading of an aspiration wet-bulb thermometer. He therefore provided a wet-bulb thermometer with a corresponding scale and patented it in 1913 under the name of "Prött-meter." Especially important is the introduction of "relative saturation," instead of the hitherto customary "relative humidity." The former refers to the maximum humidity at the temperature of the wet-bulb thermometer, the latter to that at the temperature of the dry-bulb thermometer. The former refers to the maximum amount of aqueous vapour which the air can actually absorb without change of temperature, the latter to the aqueous vapour which it contains theoretically. There can be no doubt that the former is practically the more important. A mathematical working out of the laws, which does not lend itself to abstraction, is followed by various suggestions for their technical application.—*E. F.*

[1] *Meteorologische Zeitschrift*, Sept., 1922, pp. 267-272.

THE REGIONAL PECULIARITIES OF THUNDERSTORM OCCURRENCE IN NORTH GERMANY.[1]

By K. LANGBECK.

[Abstract reprinted from *Science Abstracts*, Apr. 25, 1923, pp. 174-175, §430.]

An inquiry based on material collected by the Preuss Meteorolog. Inst. from 1901 to 1910. In considering the question of the yearly and daily periods a system of comparison was adopted which attempted in the first place a general mean [percentage] distribution for the whole district under observation, and, secondly, to ascertain the "anomalies." The regional differences thus revealed lead to a point in connection with the origin of thunderstorms hitherto insufficiently considered, which touches the contrast between continental and oceanic climate, and finds an analogy on a small scale in the contrast between mountain and valley. The following questions were investigated: (1) A relative estimate of the different districts as regards the formation of storms; (2) the yearly period of storm occurrence; (3) the [percentage] distribution of storm direction. The influence of a climatic temperature contrast on the generation of electric phenomena which is revealed by the North German observations enables us to understand the general distribution of storm frequency on the earth. Wherever there are, owing to opposition between land and sea, mountain and valley, warm and cold air currents or ocean currents, or differences in temperature and humidity, there must be increased storm frequency. Exceptions under special climatological and aerological conditions may be explained by the absence in such cases of sufficient masses of warm, humid air.—*E. F.*

[1] *Meteorologische Zeitschrift*, Sept., 1922, pp. 257-263.

ATMOSPHERICS IN CARIBBEAN DURING THE SPRING OF 1923.

A letter under date May 21, 1923, received from the superintendent of the radiotelegraph department of the United Fruit Co., stationed at Swan Island, contains the following paragraph:

As mentioned in my former letter, atmospheric disturbances in this vicinity have been detrimental to our radio service so far this season;

in fact we have never before experienced such severe electrical disturbances as has been the case during the past two months * * *.

RAINFALL AT PORTO VELHO, BRAZIL.[1]

The monthly and annual precipitation at Porto Velho, Brazil, as recorded by the Madeira Mamore Railway Co. has been published;[2] we have now received the statistics for 1921 and the first 6 months of 1922, as in the table below.

Monthly and annual precipitation (inches) for Porto Velho, Brazil.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
1921	24.52	11.30	18.83	12.13	10.22	2.63	0.51	4.37	2.52	8.67	14.67	20.36	130.73
1922	28.57	24.97	32.71	9.41	4.71	4.15	.....	.....	.....	.....	.....	.....	.....

[1] Communicated by Dr. F. L. Hoffman, Prudential Life Insurance Co.
[2] MO. WEATHER REV., Aug., 1922, 50: 416.

—*A. J. H.*

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SOLAR OBSERVATIONS.

SOLAR AND SKY RADIATION MEASUREMENTS DURING APRIL, 1923.

By HERBERT H. KIMBALL, In Charge, Solar Radiation Investigations.

For a description of instruments and exposures, and an account of the method of obtaining and reducing the measurements, the reader is referred to this REVIEW for April, 1920, **48**:225, and a note in the REVIEW for November, 1922, **50**:595.

From Table 1 it is seen that direct solar-radiation intensities averaged slightly below the normal values for April at Lincoln, Nebr., and close to normal at Washington, D. C., and Madison, Wis.

Table 2 shows for all three stations only unimportant departures from the average total amount of solar and sky radiation received on a horizontal surface during April.

Skylight-polarization measurements obtained at Washington on 12 days, give a mean of 52 per cent, with a maximum of 64 per cent on the 24th. At Madison, measurements obtained on four days during the last half of the month give a mean of 58 per cent, with a maximum of 65 per cent on the 18th. These are slightly below average values for April at the respective stations.

TABLE 1.—*Solar radiation intensities during April, 1923.*

[Gram-calories per minute per square centimeter of normal surface.]

Washington, D. C.

Date.	Sun's zenith distance.										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon.
	75th mer. time.	Air mass.									Local mean solar time.
		A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Apr. 2	2.62	.....	0.71	0.83	1.05	1.38	1.11	.....	.....	.....	2.36
6	4.17	.....	0.65	0.83	1.03	1.41	1.03	0.79	0.64	.....	3.99
7	5.56	.....	0.66	0.91	.....	1.34	0.84	.....	.....	.....	4.37
9	2.49	0.73	0.85	1.00	1.22	.....	.....	.....	.....	.....	2.74
11	5.79	.....	0.57	0.75	0.96	.....	.....	.....	.....	.....	4.57
12	5.56	.....	.....	.....	0.89	1.09	.....	.....	.....	.....	5.79
18	3.00	.....	0.87	1.10	1.30	.....	.....	.....	.....	.....	2.87
19	3.30	0.71	0.82	0.94	1.08	1.41	1.02	0.84	0.70	0.59	3.63
20	7.57	.....	.....	.....	.....	1.35	0.98	0.81	0.72	0.60	4.37
21	7.04	.....	.....	.....	0.86	.....	.....	.....	.....	.....	7.57
23	6.50	.....	.....	0.80	.....	.....	.....	.....	.....	.....	7.57
24	3.45	0.85	0.94	1.06	1.25	1.39	1.07	0.89	0.74	0.59	3.15
25	4.57	.....	.....	0.98	1.18	1.41	1.05	0.83	0.71	0.59	4.17
26	3.81	.....	.....	.....	1.12	.....	.....	.....	.....	.....	3.30
Means	.....	**0.76**	**0.76**	**0.92**	**1.09**	**1.35**	**1.01**	**0.83**	**0.70**	**0.59**	.....
Departures	.....	**+0.07**	**+0.01**	**+0.04**	**+0.02**	**−0.02**	**−0.06**	**−0.06**	**−0.03**	**+0.01**	.....

Madison, Wis.

Apr. 5	3.00	.....	.....	.....	.....	1.44	1.25	1.09	.....	.....	3.30
12	3.30	.....	.....	.....	1.33	1.52	1.10	.....	.....	.....	4.37
14	4.37	.....	.....	.....	1.24	.....	.....	.....	.....	.....	3.81
17	3.99	.....	.....	.....	1.29	1.50	.....	.....	.....	.....	3.30
18	4.57	.....	.....	1.04	1.23	1.47	1.07	.....	.....	.....	5.36
19	5.36	.....	.....	.....	.....	1.36	.....	.....	.....	.....	8.18
20	7.29	.....	.....	.....	0.97	.....	.....	.....	.....	.....	8.81
25	4.17	.....	.....	.....	1.16	.....	.....	.....	.....	.....	5.16
28	4.95	.....	.....	.....	1.20	1.41	.....	.....	.....	.....	5.36
30	5.79	.....	.....	.....	1.00	.....	.....	.....	.....	.....	5.79
Means	.....	.....	.....	**(1.04)**	**1.18**	**1.45**	**1.14**	**(1.09)**	.....	.....	.....
Departures	.....	.....	.....	**−0.05**	**−0.05**	**+0.03**	**−0.09**	**+0.01**	.....	.....	.....

Lincoln, Nebr.

Date.	Sun's zenith distance.										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon.
	75th mer. time.	Air mass.									Local mean solar time.
		A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	1 1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Apr. 5	4.17	.....	.....	0.67	1.04	.....	.....	.....	.....	.....	4.37
9	3.81	.....	.....	.....	1.31	.....	.....	.....	.....	.....	2.62
10	3.00	.....	0.80	0.93	1.19	.....	.....	.....	.....	.....	3.30
11	5.36	.....	.....	.....	.....	.....	.....	0.82	.....	.....	6.76
14	4.17	0.96	1.02	1.11	1.35	.....	.....	.....	.....	.....	3.45
17	3.63	.....	.....	.....	1.15	1.41	.....	.....	.....	.....	3.81
18	4.17	0.56	0.73	0.94	1.09	1.26	0.99	0.69	.....	.....	5.36
24	4.75	0.89	0.97	1.15	1.35	1.50	1.20	.....	.....	.....	6.50
30	7.29	.....	.....	.....	1.15	.....	.....	.....	.....	.....	7.57
Means	.....	**0.80**	**0.88**	**0.96**	**1.20**	**1.39**	**(1.10)**	**(0.76)**	.....	.....	.....
Departures	.....	**+0.04**	**+0.03**	**−0.04**	**−0.02**	**−0.06**	**−0.07**	**−0.20**	.....	.....	.....

*Extrapolated.

TABLE 2.—*Solar and sky radiation received on a horizontal surface.*

Week beginning.	Average daily radiation.			Average daily departure for the week.			Excess or deficiency since first of year.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Apr. 2	362	324	435	− 28	−57	+ 5	−2,836	−789	+ 479
9	306	445	497	−100	+49	+74	−3,534	−445	+1,000
16	508	443	429	+ 84	+28	+ 1	−2,948	−248	+1,007
23	430	457	425	− 16	+19	−23	−3,058	−117	+ 845

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS.

NORTH ATLANTIC OCEAN.

By F. A. YOUNG.

The average pressure for the month was not far from the normal at land stations in Newfoundland and on the Atlantic coasts of Canada and the United States, as well as in the West Indies. It was somewhat above normal in the Azores and Bermudas, and also at Lerwick, Shetland Islands, while considerably below in England and Ireland, due to the period of low pressure in that locality that extended from the 6th to the 15th.

Fog was unusually prevalent over the Grand Banks, as it was reported on 17 days in the region between the 40th and 45th parallels and 45th and 55th meridians. The number of days in which it was observed was also considerably above the normal along the coast of the United States, north of Hatteras, and slightly above over the middle section of the steamer lanes, while fog was apparently rare in the vicinity of the European coast.

Considering the ocean as a whole, the stormy weather that had prevailed since August still continued, as the number of days on which winds of gale force were reported was considerably greater than usual, although unevenly distributed as to location. Gales were unusually numerous in the region between the 30th and 40th parallels and the 65th and 80th meridians, and also over the eastern section of the steamer lanes, while in mid-ocean the number of days on which they occurred did not differ materially from the normal as shown on the Pilot Chart.

On the 1st and 2d there was an area of unusually high pressure over the middle Atlantic States, while the atmospheric conditions in the West Indies were about normal. The steep gradient was responsible for stormy weather between the 70th meridian and the Georgia and Florida coasts, accompanied by comparatively high barometric readings. Storm log:

American S. S. *El Alba:*

April 1, 7 a. m. in latitude 31° 12′ N., longitude 79° 30′ W., barometer 30.39 inches, wind NE., 8, weather cloudy. 4 p. m. fresh NE. gale, high sea, overcast. 7 p. m. in latitude 33° N., longitude 77° 30′ W., barometer 30.62 inches, wind NE., 7, weather cloudy. Midnight, wind and seas moderating, overcast and squally.

American S. S. *Imlay:*

Gale began on the 1st, wind NE. Lowest barometer 30.07 inches at 7 p. m. on the 1st, wind NE., 8, in latitude 25° 30′ N., longitude 74° 15′ W. End on the 2d. Highest force of wind 9; shifts SE.–NE.–ENE.–SE.

On the 1st, St. Johns, Newfoundland, was near the center of an area of low pressure, and southwesterly gales prevailed in the southeasterly quadrants, as shown by following storm log:

U. S. Coast Guard cutter *Tampa:*

Gale began on the 1st, wind WSW. Lowest barometer 29.83 inches at 6 a. m. on the 1st, wind SW., in latitude 44° 05′ N., longitude 47° 07′ W. End at 3 p. m. on the 1st, wind NW. Highest force of wind 9; shifts WSW.–SW.–W.–NW.

From the 3d until the 5th there was no unusual weather, taking the ocean as a whole, although a few reports of moderate gales were received from vessels in the middle and eastern sections of the steamer lanes.

On the 6th there was a disturbance central near latitude 55° N., longitude 20° W., and gales were also reported from a limited area between the Bermudas and the 40th parallel. Storm logs:

British S. S. *Homeric:*

Gale began on the 6th, wind SW. Lowest barometer 29.34 inches at 3 a. m. on the 6th, wind SW. 4, in latitude 49° 07′ N., longitude 17° 04′ W. End on the 6th, wind NW. Highest force of wind 8; shifts SW.–NW.

British S. S. *Lingfield:*

Gale began on the 6th, wind SSW. Lowest barometer 29.82 inches at midnight on the 6th, wind SSW. 8, in latitude 36° 17′ N, longitude 67° 24′ W. End on the 7th, wind NNE. Highest force of wind 8; shifts 16 points.

Between the 7th and 10th heavy weather prevailed over the eastern section of the steamer lanes, with unusually low pressure along the British coast; the storm area varied considerably from day to day, both in extent and intensity, reaching its maximum on the 9th. Charts VIII and IX show the conditions on the 9th and 10th, respectively.

British S. S. *Cadillac:*

Gale began on the 7th, wind W. Lowest barometer 29.57 inches at 4 p. m. on the 9th, wind NW., in latitude 46° 26′ N., longitude 28° 42′ W. End on the 11th, wind N. Highest force of wind 10, NW.; shifts WNW.–NW.

American S. S. *Glen Ridge:*

Gale began on the 8th, wind NW. Lowest barometer 29.31 inches at 4 p. m. on the 8th, wind NW., in latitude 47° 37′ N., longitude 27° 45′ W. End on the 9th, wind NNE. Highest force of wind 12; shifts N.–NNW.

American S. S. *St. Anthony:*

Gale began on the 9th, wind NW. Lowest barometer 29.42 inches at 6.30 a. m. on the 9th, wind NW., 9, in latitude 44° 36′ N., longitude 24° W. End on the 9th, wind NW. Highest force of wind 10, NW.; shifts not given.

On the 11th and 12th comparatively moderate weather prevailed over this region, but by the 13th the area of low pressure in the vicinity of Great Britain became intensified, with the lowest barometric readings slightly over 29 inches and westerly gales in the southerly quadrants.

On the 14th the barometer began to rise slowly off the European coast, although there was little change in the storm area since the previous day.

On the 14th and 15th gales were encountered in the region between the Bermudas and Nantucket, and also by a few vessels in widely scattered positions, interspersed with reports indicating moderate conditions. Storm logs:

Norwegian M. S. *George Washington:*

Gale began on the 12th, wind NW. Lowest barometer 29.68 inches at 8 a. m. on the 13th, wind NW., 9, in latitude 48° 40′ N., longitude 23° 55′ W. End on the 14th. Highest force of wind 9, WNW.; shifts not given.

British S. S. *Hydraspes:*

Gale began on the 13th, wind NE. Lowest barometer 29.74 inches at 10 p. m. on the 13th, wind ENE., 8, in latitude 37° 31′ N., longitude 68° 18′ W. End on the 14th, wind E. Highest force of wind 8, ENE.; steady ENE.

On the 15th and 16th conditions were similar to those on the 14th, and on the 17th moderate winds were the rule over the entire ocean with the exception of a limited area off the coast of Ireland, as shown by the following storm log:

American S. S. *Saguache:*

Gale began on the 15th. Lowest barometer 29.56 inches at 3 p. m. on the 16th, wind S., 8, in latitude 49° 17′ N., longitude 17° 09′ W. End on the 17th. Highest force of wind 9; steady S.

On the 17th an area of low pressure central near St. Johns, Newfoundland, was apparently surrounded by moderate winds, although few reports were received from the northern quadrants. This LOW moved rapidly eastward, increasing in intensity, and on the 18th the center was near latitude 47° N., longitude 30° W. It continued its easterly movement, although with reduced speed, and on the 18th the center was not far from the coast of southern Europe, the storm area extending as far south as the 30th parallel. Storm logs:

British S. S. *Ventura de Larrinaga:*

Gale began on the 18th, wind WSW., 7. Lowest barometer 29.57 inches at 4 a. m. on the 18th, wind NNW., 9, in latitude 43° 30′ N., longitude 29° W. End on the 19th, wind WNW. Highest force of wind 9, NW.; shifts WSW.–W.–NNW.

American S. S. *President Polk:*

Gale began on the 18th, wind NE., 7. Lowest barometer 29.06 inches at 6 p. m. on the 18th, wind NE., 7, in latitude 48° 45′ N., longitude 24° 35′ W. End on the 20th, wind NE. Highest force of wind 9; shifts WSW.–NE.–NNE.

Dutch S. S. *Salawati:*

Gale began on the 18th, wind WSW. Lowest barometer 29.84 inches at 8 a. m. on the 19th, wind WNW., 8, in latitude 37° 10′ N., longitude 18° 30′ W. End on the 20th, wind NW. Highest force of wind 10, WNW.; shifts WSW.–WNW.

British S. S. *Ribera:*

Gale began on the 19th, wind WSW. Lowest barometer 29.46 inches at 10 a. m. on the 21st, wind W., 8, in latuitde 34° 24′ N., longitude 10° 07′ W. End on the 23d, wind SW. Highest force of wind 8, NW.; shifts NW.—W. by N.

On the 19th St. Johns, Newfoundland, was again near the center of a LOW that was responsible for gales over the region between the 30th and 45th parallels and the 50th and 60th meridians. Storm logs:

Dutch S. S. *Nieu Amsterdam:*

Gale began on the 19th, wind SSE. Lowest barometer 29.26 inches on the 19th, wind NW., 4, in latitude 40° 37′ N., longitude 56° 11′ W. End on the 19th, wind S. Highest force of wind 9; shifts SW.–NW.

American S. S. *Wildwood:*

Gale began on the 19th, wind S. Lowest barometer 29.76 inches at 7 p. m. on the 19th, wind WSW., 8, in latitude 31° 50′ N., longitude 58° 12′ W. End on the 20th, wind WNW. Highest force of wind 8; shifts S.–WNW.

On the 18th and 19th light to moderate winds were recorded at the land stations at Charleston, S. C., and Jacksonville, Fla., although on both dates a vessel only a short distance south of the former station encountered a strong northerly gale, as shown by following storm log:

Danish S. S. *Fredensbro:*

Gale began on the 18th, wind NNW. Lowest barometer 29.95 inches at 8 a. m. on the 18th, wind NNW., 9, in latitude 27° 32′ N., longitude 79° 35′ W. End on the 19th, wind NNE. Highest force of wind 10, N.; shifts NNW.–N.

The daily weather map for the 20th shows a trough of low pressure over the western part of the Gulf of Mexico, and southerly winds of gale force prevailed a short distance south of New Orleans. Storm log:

American S. S. *El Sud:*

Gale began on the 20th, wind S. Lowest barometer 29.92 inches at 1 a. m. on the 20th, wind S., 7, in latitude 28° 45′ N., longitude 91° 30′ W. End on the 20th, wind SSE. Highest force of wind 7, SSE.; shifts S.–SE.–SSE.

On the 21st and 22d there was one depression in the vicinity of Newfoundland and Nova Scotia and a second off the coast of southern Europe. Moderate conditions prevailed over the ocean as a whole, although a few

vessels in widely scattered positions encountered heavy weather. Storm log:

British S. S. *Araguaya:*

Gale began on the 22d, wind WSW., 7. Lowest barometer 29.76 inches at 7 a. m. on the 22d, wind WSW., 7, in latitude 37° 26′ N., longitude 69° 48′ W. End on the 23d, wind SW., 7. Highest force of wind 8, SW.; wind WSW. to SW. throughout.

The western disturbance remained nearly stationary until the 27th, when it began to move slowly eastward, and on the 28th the center was apparently a short distance east of St. Johns, Newfoundland; it was comparatively slight in intensity, and the only gales reported were on the 24th and 25th from a restricted area between the Bermudas and Nantucket, and on the 27th in the region between the 35th and 40th parallels and 45th and 50th meridians. Storm log:

American S. S. *Abron*:

Gale began on the 24th, wind NW. Lowest barometer 29.53 inches at 8 a. m. on the 25th, wind NW., 7, in latitude 38° N., longitude 67° W. End on the 26th, wind N. Highest force of wind 8, NW.; steady NW.

On the 25th and 26th a well-developed area of low pressure covered the greater part of the North Sea, and winds of gale force were recorded at the land stations at Lerwick, Shetland Islands, and also at Portland Bill on the south coast of England. Storm log:

British S. S. *Finchley:*

Gale began on the 24th, wind S. Lowest barometer 29.25 inches at 5 p. m. on the 25th, wind W., 8, in latitude 57° N., longitude 9° W. End on the 26th, wind NNE. Highest force of wind 8; shifts W.–NNE.

On the 29th there appeared a vigorous disturbance off the American coast, between New York and Charleston, that moved northeastward, and on the 30th was central between Portland and Eastport, Maine. The storm area was of limited extent, but vessels west of the 60th meridian experienced strong southerly to westerly gales. Storm log:

American S. S. *Chester Sun:*

Gale began on the 28th, wind S. Lowest barometer 29.42 inches at 9:35 p. m. on the 29th, wind SSW., in latitude 35° 48′ N., longitude 75° 19′ W. End on the 29th, wind NNW. Highest force of wind 11; shifts SSW.–NNW.

On the 29th and 30th moderate gales were also reported by a few vessels in the eastern section of the steamer lanes. Storm logs:

British S. S. *Norfolk Range:*

Gale began on the 29th, wind NE., 7. Lowest barometer 29.58 inches at 7 a. m. on the 29th, wind NE., 7, in latitude 54° 40′ N., longitude 26° 47′ W. End on the 30th wind NNE., 6. Highest force of wind 9; shifts NE.–NNE.

British S. S. *Comanchee:*

Gale began on the 29th, wind WSW. Lowest barometer 29.44 inches at 10 a. m. on the 30th, wind WSW., 7, in latitude 52° 46′ N., longitude 16° 52′ W. End on May 1, wind NW. Highest force of wind 8; shifts WSW.–N.–NW.

NORTH PACIFIC OCEAN.

By WILLIS E. HURD.

There was much fine weather over the North Pacific Ocean during April, although the fluctuating cyclonic activity over the northern area seemed to be much more pronounced and the conditions more unsettled than during March. Indeed, the wind on the 1st, 2d, and 12th attained a higher force, 11 to 12, than was reported for the preceding month. On the 1st and 2d, also, the lowest pressures of the two months occurred.

In the Hawaiian area the wind movement at Honolulu was somewhat higher than the average, being 10.7 miles per hour as compared with the 19-year average of 9.1 miles. The highest velocity was 30 miles from the east on the 29th, and the prevailing direction was east. For the greater part of April Honolulu lay on the southwestern slope of the North Pacific HIGH. On the 24th to 26th it lay within a depression which finally disappeared without having taken on apparent progressive movement. That the depression developed some slight intensity, however, is evidenced by an observation of the American S. S. *President Pierce*, in latitude 25° 10′ N., longitude 166° 30′ W., on the 25th, when a gale of force 8 from the north-northwest was observed, pressure 29.78 inches. The gale on the 29th at Honolulu was due to the rather steep gradient on the southern slope of the high-pressure area, which at this time had shifted to the north of Hawaii.

In the tropical storm regions no cyclonic activity of moment seems to have occurred, and only a few scattered gales disturbed the general serenity. On the 19th the northeast monsoon was reported of gale force, accompanied by rain and fog, near the lower entrance to the Formosa Channel; and on the same and other dates, at the opposite extreme of the ocean, the Gulf of Tehuantepec was swept by intermittent northerly to westerly gales.

Off the Mexican and Central American coasts light northwesterly winds were of frequent occurrence, but interspersed with variable breezes. In the main the weather experienced by the American S. S. *Venezuela* from the 12th to the 26th, while steaming up the coast from Panama toward San Pedro, is descriptive of the typical spring conditions in these waters. Captain W. J. Allen thus commented:

In April on the west coast of Central America it was observed the winds were very variable—no land nor sea breezes prevailing—light breezes from any quadrant and frequent calms. Clear and cloudy, frequently overcast and very hazy at night, with threatening rain, but no heavy showers.

Respecting the traveling storms of this month, several crossed Japan, coming from the Asiatic continent. Pressure was low over this area on the 4th and 5th, 7th to 12th, 18th and 19th, and 27th to 29th. Dangerous gales occurred over the Japan Sea on the 12th, particularly. The Canadian S. S. *Canadian Prospector* reported a "fierce storm," with violent squalls of hurricane force, overcast and misty, wind NW. to N., in latitude 37° 41′ N., longitude 134° 04′ E., lowest pressure 28.86 inches. Westerly gales of force 8 to 10 were reported by several vessels immediately to the eastward of Japan on this date.

Among the storms, or LOWS, that entered the American continent, nearly all were offshoots from the prevailing cyclonic areas to the westward, rather than eastward-moving storms in their entirety. These secondary developments entered the coast at some point between Oregon and Alaska on the 2d, 6th, 15th, 16th, 20th, 24th, and 30th.

The severe disturbance of the 1st to 2d of April, of which mention was made in the report on the weather of March, developed hurricane violence. It was central on the 1st in about 48° N., 177° E., and on the 2d in approximately 50° N., 166° W. On the 2d another violent cyclone was central near 48° N., 160° E., and on the 3d near 48° N., 170° E. Both storm centers filled up considerably on the 4th. The lowest pressure observed in connection with these disturbances was 28.20 inches, reported by the Japanese S. S. *Kaga Maru* as occurring early on the morning of the 2d, in latitude 50° N., longitude 176° 30′ E. The minimum reading on the 1st was 28.24 inches, as noted in the preceding report. The *Kaga Maru*, steaming toward Yokohama,

had scarcely emerged from the first storm area than she entered the second, and again experienced westerly winds of storm force, though of somewhat less violence.

On the 5th a small storm of some intensity appeared off the coast of Washington, at which time the Weather Bureau station at North Head reported a maximum wind velocity of 65 miles from the south, lowest pressure 29.58 inches, on the 6th.

Gales of force 7 to 10 were observed in middle latitudes and longitudes on the 6th to 8th and 11th to 14th, lowest pressure, 29.16 inches, on the 13th. On the 14th and 15th, in connection with a strong LOW then covering the Gulf of Alaska and adjacent waters to the southward, several vessels reported gales of force up to 10 and pressures below 29.00 inches. The Japanese S. S. *Shidzuoka Maru* experienced the lowest pressure, 28.63 inches, with a northwest gale, in latitude 49° 24′ N., longitude 145° 44′ W., on the 14th; and the American S. S. *Dellwood* on the same date encountered an east gale, force 10, in 58° 10′ N., 136° 39′ W. On the 15th the *Dellwood* reported a barometer "down to 28.90 inches (uncorrected) for six hours," with wind still high during the morning hours, while in and near latitude 59° 08′ N., longitude 141° 35′ W.

On the 22d to 24th the British S. S. *Empress of Asia* passed through one storm central near the Peninsula of Alaska, and entered another over the western Aleutians. On the 22d, in approximately latitude 52° N., longitude 154° W., she experienced a wind from the south, force 10, pressure 29.18 inches; on the 23d, in 52° N., 164° W., she observed a northwest wind, force 10, pressure 29.56 inches; and on the 24th, in 51° N., 176° W., a southwest wind, force 8, pressure 29.64 inches. These storms were of the Aleutian LOW type.

Among the few gales thus far reported for the period April 25 to 30, the American S. S. *Stockton* experienced one from the west, force 8, in 46° 41′ N., 169° 06′ W., pressure 29.97 inches, on the 29th. On the same date the Japanese S. S. *Yokohama Maru* encountered a west-northwesterly gale, force 8, lowest pressure 29.42 inches, in 50° 14′ N., 139° 04′ W. On the 30th North Head recorded a maximum wind velocity of 58 miles from the south, in connection with a storm area central to the westward of British Columbia.

On the 26th of April Observer Dumaresq, of the American S. S. *Atlanta City*, San Pedro toward Yokohama, the wind being light at the time, witnessed a peculiar condition which he thus describes:

> The sharpest shift of wind and sea I have ever seen occurred April 26, at 4 p. m., in latitude 34° 19′ N., longitude 150° 20′ E. Wind and sea had been SW. all day, and as suddenly as though a fan had been turned both wind and sea shifted to NW. We could plainly see a narrow stretch of confused sea where the two met.

During the greater part of the month the series of low-pressure areas which dominated the weather over the Aleutian region and over a wide stretch of ocean from the Peninsula of Alaska southeastward, were more energetic even than during March. In general they formed two centers of activity, one of which may be placed nearly over Dutch Harbor on the west and the other over the northern portion of the Gulf of Alaska on the east.

The North Pacific high-pressure area, normally central to the northeast of Hawaii, was generally well developed after the 10th of the month. Prior to that it was distorted and shallow, with low-pressure areas occupying a portion of its normal area on the northeast or northwest. At the close of the month its center had moved to the westward and northward, with a crest of 30.50 inches near latitude 40° N., longitude 155° W.

Pressure was below normal over the eastern part of the ocean, as shown by observations at the island stations. In this respect conditions were similar to those of the preceding month. In April, however, the greatest relative deficiency was at Dutch Harbor (−0.28 inch), whereas in March it was at Honolulu (0.07 inch). The average pressure at Dutch Harbor, based on p. m. reports, was 29.57 inches. The highest pressure, 30.16 inches occurred on the 25th; the lowest, 28.82 inches, on the 8th. Absolute range, 1.34 inches. At Honolulu the mean p. m. pressure was 30.02 inches, or 0.04 inch below normal. The highest pressure, 30.15 inches, occurred on the 12th; the lowest, 29.79, on the 25th. At Midway Island the mean p. m. pressure was 30.11 inches, or 0.02 inch below normal. The highest pressure, 30.28 inches, occurred on the 28th; the lowest, 29.88, on the 29th and 30th.

Fog was observed almost daily over the northern and central routes both east and west of the 180th meridian, but was of particularly frequent occurrence after the middle of the month. It was noted on the China coast on several days as far south as Swatow and Hongkong.

DETAILS OF THE WEATHER IN THE UNITED STATES.

GENERAL CONDITIONS.

ALFRED J. HENRY.

Aside from the variability characteristic of a transition month, the weather of April, 1923, presented no distinctive features of consequence.

Many secondary cyclonic systems had their origin over the southern Plateau and Rocky Mountain region, and when such is the case the anticyclones almost invariably appear in Canadian Provinces and move east-southeast as was the case in the current month—see Charts I and II. The usual details follow.

CYCLONES AND ANTICYCLONES.

By W. P. DAY.

Fifteen low-pressure areas developed over the south and southwest or entered the country on the Pacific coast. This is an unusual number for the season of the year and would be rather excessive even for a winter month. However, the dampening effect on the movements of the cyclones and anticyclones, which is a normal occurrence in April, was quite noticeable before the end of the month. This slowing up, and in some cases reversal of the general circulation, is due to the change in pressure distribution over land and water areas. This change is slow and masked by the passing cyclones and anticyclones; but as the continents rapidly warm, we see them change from areas covered normally by high pressure to areas of indifferent or low pressure, and at the same time the pressure is rising over the relatively colder water areas.

FREE-AIR SUMMARY.

By L. T. SAMUELS, Meteorologist.

Free-air conditions for the month averaged in most cases close to their normal values. (See Table 1.) Negative temperature departures obtained at nearly all levels at Broken Arrow, Due West, and Royal Center,

while positive departures were found at Drexel, Ellendale, and Groesbeck.

Relative-humidity departures were particularly small and mostly negative with the exception of Groesbeck, where positive departures prevailed throughout, becoming larger with increasing altitude.

Vapor-pressure departures were in general agreement with those for temperature.

In Table 2 are shown the resultant wind velocities and directions for the month and their normal values. It will be observed that the deviations from the normals are but slight in most cases. The resultant velocities at the northern stations indicated mostly an excess, however, while at the southern stations the velocities were below the normals.

At this season of the year when horizontal temperature gradients become less marked than in winter, occurrences of extreme wind velocities in the free-air decrease proportionally, while it is found that easterly winds extend to greater altitudes than during the colder season. Winds of 40 m. p. s. or more were observed as follows:

Station.	Date.	Velocity.	Direction.	Altitude.
		m. p. s.		*m.*
Camp Alfred Vail, N. J.	30	46	W.	1,000
Due West, S. C.	5	44	WSW.	2,500
Mitchel Field, N. Y.	24	48	NNW.	2,000

The following stations reported winds at 5,000 meters elevation, or higher, having an east component:

Station.	Date.	Velocity.	Direction.	Altitude.
		m. p. s.		*m.*
Broken Arrow, Okla.	18	6	ENE.	10,000
Drexel, Neb.	28	7	NE.	9,000
Ellendale, N. Dak.	17	26	NNE.	10,000
Lansing, Mich.	17	26	NNE.	5,000
Camp Lewis, Wash.	2	7	SSE.	5,000
Do.	4	3	NE.	5,000
Do.	23	18	NNE.	8,000
Do.	24	24	NNE.	7,000
Do.	25	13	NE.	6,000
San Francisco, Calif.	24	6	E.	6,000
Do.	25	12	NNE.	6,000

The pilot-balloon observations made at Ellendale on the 17th and 18th are of special interest in that they show a complete reversal of wind streams occurring at great elevations within a period of 24 hours. On the morning of the 17th with an extensive HIGH central over Iowa, the surface winds were south-southwesterly at this station veering with increasing altitude to northerly at 3,000 meters, remaining northerly and north-northeasterly to 10,000 meters. On the morning of the 18th the HIGH was central to the southward over the lower Mississippi River Valley and a LOW was approaching from the Canadian Northwest. At this time south-southwesterly winds extended from the surface to 10,000 meters indicating thereby the wide variations which may occur in short intervals of time in the so-called "upper westerlies." In continuation of the characteristic effects produced by these upper air currents it is of interest to note the temperature distribution prevailing in the higher levels on the 18th (surface-pressure distribution at this time described above). On this date simultaneous kite observations were made at Ellendale, Drexel, Royal Center, and Due West and the temperatures observed at each station at corresponding elevations above the sea are given in the following table:

Station.	Surface.	Altitudes in meters above M. S. L.									
		250	500	750	1,000	1,250	1,500	2,000	2,500	3,000	3,500
Ellendale	11.3	.....	11.8	13.2	15.6	14.8	13.0	9.2	6.0	2.4	−1.4
Drexel	11.5	.....	12.3	11.0	12.4	11.6	10.0	5.9	4.0	1.0	−2.4
Royal Center	11.0	10.7	9.3	7.2	4.7	2.5	0.8	−0.8	−2.3	.....	.....
Due West	10.5	10.1	7.4	5.2	3.5	1.9	0.4	−3.5	−6.9	−9.6	−12.6

The persistent decrease in the temperature from Ellendale to Due West is striking and must, it seems, be attributed to the source of the air overrunning these places. The temperature in the free air appears unquestionably as a function of the source of the air supply.

The unusually high altitude of 5,725 meters above the ground was reached during a kite flight at Groesbeck on the 14th. This was made possible by the favorable winds blowing from the southeastern quadrant of an elongated high-pressure area extending in a NW–SE direction across the western half of the country. The temperature gradient for this observation showed a lapse rate from the surface to 1,000 meters equal to that found for the normal for the month, while from 2,000 to 5,000 meters the lapse rate greatly exceeded the monthly normal at this station. The wind velocity from the surface to the highest level reached did not exceed 18 m. p. s., thus making conditions ideal for kite flying.

The following note by the official in charge of the Due West station was made relative to a series of kite flights in progress at that station on the 23d.

During the fourth flight on April 23d, the kites were caught in a thundersquall and beaten down almost to the ground. While the wire was down over the trees and on the ground, a ball of fire came in over the wire and exploded in the reel house under the feet of one of the men on duty at the time. There was no damage to the reel house and the men were unhurt. Distant thunder was heard in the south a few minutes after the explosion and the kites were seen to have broken away. It is thought that lightning struck a tree over which the kite wire was resting and that the lightning went to the ground through the tree and the reel. Only a few places were found in the wire that had been fused and the end of the wire to which the two leading kites were attached showed fusing where it probably rested over the tree that was struck.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during April, 1923.*

TEMPERATURE (°C.).

Altitude. m. s. l. (meters).	Broken Arrow, Okla. (233 meters.)		Drexel, Nebr. (396 meters.)		Due West, S. C. (217 meters.)		Ellendale, N. Dak. (444 meters.)		Groesbeck, Tex. (141 meters.)		Royal Center, Ind. (225 meters.)	
	Mean.	Departure from 5-year mean.	Mean.	Departure from 8-year mean.	Mean.	Departure from 3-year mean.	Mean.	Departure from 6-year mean.	Mean.	Departure from 5-year mean.	Mean.	Departure from 5-year mean.
Surface	14.8	−0.3	9.0	+0.7	16.7	−0.9	4.7	−0.5	19.4	+1.0	9.5	−1.3
250	14.7	−0.3	.....	.....	16.4	−0.8	.....	.....	18.6	+0.9	9.2	−1.4
500	13.0	−0.2	8.2	+0.6	14.3	−0.5	4.6	−0.3	16.9	+0.9	6.5	−1.7
750	11.5	−0.3	6.7	+0.8	12.5	−0.5	3.6	+0.2	15.8	+1.0	5.3	−1.4
1,000	10.6	−0.2	5.9	+1.0	11.2	−0.4	2.5	+0.3	14.8	+0.9	4.1	−1.3
1,250	9.6	−0.1	5.4	+1.4	10.0	−0.3	1.7	+0.6	13.7	+0.7	3.0	−1.1
1,500	8.4	−0.2	4.7	+1.7	8.9	−0.1	0.7	+0.7	12.9	+0.6	1.9	−1.1
2,000	5.8	−0.3	2.6	+1.7	5.9	−0.3	−1.4	+0.9	10.3	+0.1	−0.3	−1.1
2,500	2.6	−0.6	−0.4	+1.2	3.4	−0.4	−3.9	+0.9	7.3	−0.2	−3.0	−1.2
3,000	−0.5	−0.5	−3.4	+0.9	0.5	−1.0	−6.9	+0.6	4.5	−0.3	−5.3	−0.7
3,500	−3.3	−0.1	−6.4	+1.0	−1.8	−0.8	−9.9	+0.4	1.4	−0.6	−7.4	−0.2
4,000	−5.7	+0.3	−9.4	+1.2	−4.7	−1.4	−12.4	+1.0	−2.0	−0.6	.....	.....
4,500	.....	.....	.....	.....	.....	.....	−15.3	+0.9	−5.0	−0.4	.....	.....
5,000	.....	.....	.....	.....	.....	.....	.....	.....	−7.9	−0.4	.....	.....

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during April, 1923*—Continued.

RELATIVE HUMIDITY (%).

Altitude, m. s. l. (meters).	Broken Arrow, Okla. (233 meters.)		Drexel, Nebr. (396 meters.)		Due West, S. C. (217 meters.)		Ellendale, N. Dak. (444 meters.)		Groesbeck, Tex. (141 meters.)		Royal Center, Ind. (225 meters.)	
	Mean.	Departure from 5-year mean.	Mean.	Departure from 8-year mean.	Mean.	Departure from 3-year mean.	Mean.	Departure from 6-year mean.	Mean.	Departure from 5-year mean.	Mean.	Departure from 5-year mean.
Surface	65	0	65	−1	60	0	71	+4	71	+1	58	−5
250	65	0	.....	.....	60	0	.....	.....	71	+2	58	−5
500	63	−1	65	−1	61	0	69	+3	70	+3	59	−3
750	62	−1	65	0	61	−1	63	−1	70	+5	58	−3
1,000	60	0	62	−1	60	−2	58	−4	67	+7	57	−3
1,250	58	0	60	−2	59	−2	55	−5	64	+9	55	−4
1,500	58	+2	60	0	55	−4	52	−6	58	+8	55	−2
2,000	54	+3	58	0	53	−2	52	−4	55	+10	56	+3
2,500	52	+3	60	+2	48	−1	49	−5	58	+14	59	+8
3,000	53	+3	62	+3	46	+3	50	−4	56	+15	60	+10
3,500	59	+3	62	+3	42	+4	45	−9	53	+10	56	+5
4,000	49	−3	57	−3	41	+3	45	−9	61	+13	.....	.....
4,500	.....	.....	.....	.....	.....	.....	54	−2	59	+12	.....	.....
5,000	.....	.....	.....	.....	.....	.....	.....	.....	73	+12	.....	.....

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressure during April, 1923*—Continued.

VAPOR PRESSURE (mb.).

Altitude, m. s. l. (meters).	Broken Arrow, Okla. (233 meters.)		Drexel, Nebr. (396 meters.)		Due West, S. C. (217 meters.)		Ellendale, N. Dak. (444 meters.)		Groesbeck, Tex. (141 meters.)		Royal Center, Ind. (225 meters.)	
	Mean.	Departure from 5-year mean.	Mean.	Departure from 8-year mean.	Mean.	Departure from 3-year mean.	Mean.	Departure from 6-year mean.	Mean.	Departure from 5-year mean.	Mean.	Departure from 5-year mean.
Surface	11.26	−0.40	7.42	+0.06	11.94	−0.73	6.14	+0.23	16.58	+1.32	6.91	−1.83
250	11.17	−0.39	.....	.....	11.74	−0.69	.....	.....	15.88	+1.39	6.81	−1.78
500	9.86	−0.40	7.05	+0.04	10.50	−0.41	5.93	+0.19	14.20	+1.50	5.75	−1.57
750	8.78	−0.39	6.38	+0.11	9.49	−0.41	4.98	−0.04	13.19	+1.83	5.17	−1.33
1,000	8.00	−0.24	5.97	+0.22	8.66	−0.45	4.21	−0.26	11.82	+1.95	4.69	−1.16
1,250	7.15	−0.24	5.48	+0.29	7.86	−0.39	3.74	−0.27	10.51	+1.96	4.22	−1.05
1,500	6.46	−0.13	5.23	+0.52	6.59	−0.65	3.32	−0.28	8.97	+1.70	3.92	−0.83
2,000	4.99	−0.12	4.31	+0.47	5.04	−0.35	2.72	−0.18	7.27	+1.71	3.27	−0.53
2,500	3.85	−0.25	3.57	+0.45	3.82	+0.01	2.11	−0.20	6.43	+1.91	2.80	−0.20
3,000	3.25	−0.21	2.96	+0.35	2.96	+0.21	1.71	−0.21	5.37	+1.85	2.38	+0.02
3,500	2.98	−0.17	2.40	+0.22	2.42	+0.32	1.29	−0.32	4.50	+1.63	1.92	−0.09
4,000	2.04	−0.33	1.78	+0.05	1.93	+0.18	1.15	−0.20	4.24	+1.86	.....	.....
4,500	.....	.....	.....	.....	.....	.....	1.16	+0.08	3.53	+1.73	.....	.....
5,000	.....	.....	.....	.....	.....	.....	.....	.....	3.53	+1.73	.....	.....

TABLE 2.—*Free-air resultant winds (m. p. s.) during April, 1923.*

Altitude, m. s. l. (meters).	Broken Arrow, Okla. (233 meters.)				Drexel, Nebr. (396 meters.)				Due West, S. C. (217 meters.)				Ellendale, N. Dak. (444 meters.)				Groesbeck, Tex. (141 meters.)				Royal Center, Ind. (225 meters.)			
	Mean.		5-year mean.		Mean.		8-year mean.		Mean.		3-year mean.		Mean.		6-year mean.		Mean.		5-year mean.		Mean.		5-year mean.	
	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel
Surface	S. 19° E.	1.6	S. 5° W.	2.9	S. 52° W.	1.3	S. 71° E.	0.4	S. 61° W.	1.7	S. 79° W.	1.6	N. 1° E.	1.2	N. 9° W.	1.6	S. 20° E.	2.3	S. 4° E.	2.5	S. 63° W.	2.4	S. 43° W.	2.6
250	S. 19° E.	1.6	S. 6° W.	3.0	.....	.....	.....	.....	S. 62° W.	1.9	S. 77° W.	1.8	.....	.....	.....	.....	S. 19° E.	2.9	S. 4° E.	3.2	S. 61° W.	2.5	S. 43° W.	2.7
500	S. 13° E.	2.7	S. 13° W.	4.4	S. 47° W.	1.8	S. 57° E.	0.5	S. 53° W.	3.1	S. 65° W.	3.1	N. 6° E.	1.1	N. 10° W.	1.4	S. 7° E.	4.0	S. 4° W.	4.8	S. 56° W.	4.5	S. 41° W.	4.6
750	S. 3° E.	3.2	S. 16° W.	5.5	S. 68° W.	2.6	S. 32° W.	0.1	S. 54° W.	4.0	S. 64° W.	4.1	N. 27° W.	0.8	N. 17° W.	0.8	S. 6° W.	4.3	S. 13° W.	5.5	S. 53° W.	5.1	S. 44° W.	6.0
1,000	S. 28° W.	2.8	S. 27° W.	6.1	S. 69° W.	4.0	S. 61° W.	0.7	S. 58° W.	5.4	S. 60° W.	5.2	N. 69° W.	2.4	N. 45° W.	1.0	S. 21° W.	4.9	S. 23° W.	6.3	S. 60° W.	5.9	S. 50° W.	6.4
1,250	S. 49° W.	3.6	S. 37° W.	6.3	S. 74° W.	4.6	S. 76° W.	1.5	S. 64° W.	7.3	S. 67° W.	7.4	N. 56° W.	3.6	N. 50° W.	1.8	S. 38° W.	5.5	S. 33° W.	6.9	S. 72° W.	6.2	S. 61° W.	6.9
1,500	S. 63° W.	3.9	S. 53° W.	7.0	S. 83° W.	6.3	S. 82° W.	2.5	S. 65° W.	9.4	S. 68° W.	8.3	N. 53° W.	4.0	N. 52° W.	2.2	S. 50° W.	6.0	S. 37° W.	7.5	N. 73° W.	4.6	S. 70° W.	7.3
2,000	S. 78° W.	5.3	S. 61° W.	8.0	N. 88° W.	7.4	W.	4.0	S. 76° W.	10.3	S. 79° W.	9.6	N. 58° W.	4.8	N. 67° W.	2.5	S. 58° W.	7.8	S. 48° W.	8.6	N. 64° W.	6.9	S. 80° W.	8.0
2,500	S. 84° W.	5.3	S. 70° W.	8.7	S. 84° W.	7.8	W.	5.8	S. 84° W.	10.2	S. 82° W.	10.4	N. 63° W.	6.3	N. 74° W.	3.7	S. 70° W.	8.3	S. 56° W.	9.5	N. 45° W.	9.0	S. 83° W.	8.3
3,000	N. 88° W.	6.2	S. 79° W.	8.4	W.	10.8	N. 83° W.	8.5	N. 83° W.	10.7	S. 86° W.	11.6	N. 76° W.	8.8	N. 76° W.	5.0	S. 70° W.	10.5	S. 61° W.	11.9	N. 32° W.	16.4	S. 84° W.	10.6
3,500	N. 85° W.	9.5	S. 86° W.	11.7	S. 80° W.	13.0	S. 85° W.	10.4	N. 69° W.	10.0	N. 84° W.	11.5	N. 83° W.	10.3	N. 79° W.	6.7	S. 81° W.	10.5	S. 69° W.	10.8	N. 22° W.	22.8	S. 76° W.	11.8
4,000	W.	13.8	S. 80° W.	14.4	N. 80° W.	15.2	N. 87° W.	12.8	N. 65° W.	12.2	N. 72° W.	13.9	N. 39° W.	6.3	N. 64° W.	7.8	S. 70° W.	9.4	S. 83° W.	13.3	.....	.....	.....	.....
4,500	S. 67° W.	24.5	S. 76° W.	18.6	N. 45° W.	20.7	N. 75° W.	13.3	N. 37° W.	9.5	N. 42° W.	13.7	N.	22.0	N. 55° W.	8.5	S. 66° W.	12.0	S. 73° W.	14.4	.....	.....	.....	.....
5,000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	N.	26.7	N. 56° W.	15.9	N. 89° W.	13.8	N. 89° W.	13.8	.....	.....	.....	.....

THE WEATHER ELEMENTS.

By P. C. DAY, Meteorologist, in Charge of Division.

PRESSURE AND WINDS.

The outstanding feature of the weather for April, 1923, was the marked anticyclone that had advanced into the central valleys by the end of March and to the more eastern districts by April 1 and off the Atlantic coast during the following 24 hours. This anticyclone was of unusual strength for a mid-spring month and dominated the weather over practically all districts between the Rocky Mountains and the Atlantic coast during its movement eastward. Clear skies and favorable conditions for radiation prevailed, and over much of the area mentioned the accompanying night temperatures were the lowest ever observed so late in spring.

Aside from the above the anticyclones of the month were usually unimportant, although a moderate area of high pressure with sharp changes in temperature moved from the upper Missouri Valley into the Great Plains on the 7th and 8th, and thence to the more eastern districts within the following 48 hours. Later in the month anticyclonic conditions prevailed over the more northern districts, particularly about the 23d and for several succeeding days, when a high-pressure area of wide extent, but lacking the strength of that at the beginning of the month and without the marked effect on temperatures usually expected, moved from the near Northwest into the Lake region and thence eastward, reaching the Atlantic coast districts about the 26th.

The cyclones of the month were mainly active only over short paths, and these were largely confined to the central and eastern districts, the storms usually losing strength as they approached the Atlantic coast.

An exception to this, however, is noted in the case of a cyclone that developed in the far Northwest on the 6th and moved to the middle Plains by the morning of the 7th and to the Great Lakes, St. Lawrence Valley, and Canadian Maritime Provinces within the following 48 hours. The precipitation attending this cyclone was mainly light and lacked the even distribution usually expected, large areas near the center of the disturbance at times receiving little or no precipitation.

A cyclone of only moderate proportions, but which gave abundant precipitation over wide areas in the Southern and Eastern States, but losing force as it approached the coast, moved slowly from Texas on the morning of the 12th to the more eastern districts during the following few days. This cyclone brought heavy

precipitation over much of Texas and the lower Mississippi Valley and locally in the Ohio Valley and near-by portions of other districts.

Cyclonic condition prevailed over the Great Plains and central valleys near the beginning of the third decade and continued for several days. This was shortly followed by another period of unsettled weather which gradually drifted eastward, giving local rains over many central, southern, and eastern districts, the falls being moderate to heavy in portions of the middle Plains and along the Atlantic coast.

The average pressure for the month was highest over the Southeastern States and along the immediate Pacific coast, conditions usually prevailing at the mid-spring period. It was low, as usual, in the far Southwest and over New England and the Canadian Maritime Provinces. On the whole the monthly averages were close to normal in practically all districts.

Compared with the averages for March, those for April were lower in all districts, and this, too, is usually the case, save along the North Pacific coast, in northern New England and over the eastern Canadian districts, where the April pressures are normally higher than those for March.

The distribution of the average pressure for the month was comparatively even, the gradients between the regions of highest and lowest pressure being small. As a result the prevailing winds were from common directions over only small areas as a rule, although in the Great Plains they were mainly from the south, as is usual at this period.

High winds over large areas due to cyclonic action were comparatively infrequent, but local high winds were quite frequent, and tornadoes of more or less severity occurred in several localities, some being attended by material loss of life and damage to property.

A list of the storms of the month, as far as reports are available, with some of the important details appears at the end of this section, and complete accounts of some appear in another portion of this issue.

TEMPERATURE.

Easter Sunday, April 1, 1923, set a new mark for low temperatures over practically all districts from the Ohio Valley and lower Lakes eastward to the Atlantic coast. In this area the minimum temperatures were lower than ever before recorded in April, and in some cases they were 10° or more lower than any previous record for so late in spring.

Aside from this severe cold period, and one materially less severe toward the end of the first decade over most districts from the Rocky Mountains eastward, there were no important temperature changes during the remainder of the month over the principal agricultural areas. On the whole, however, the first half of the month was decidedly cold over nearly all central and eastern districts and moderately warm in the far West. On the other hand, the latter half of the month was mainly slightly warmer than normal over central and eastern districts, while cool weather for the season prevailed to the wesward.

For the month as a whole the temperature was below normal over the greater part of the country, but the deficiencies were mainly small. Over a small area along the Atlantic coast from eastern Virginia to southern New England the averages for the month were slightly higher than normal, and similar conditions prevailed near the Gulf coast, over the central and southern Great Plains, and along the immediate Pacific coast.

The warmest periods of the month were about the 15th to 19th, from the Great Plains westward; and about the 21st to 23d, from the Mississippi Valley eastward.

At Walla Walla, Wash., and Portland, Me., the maximum temperatures on the 15th and 21st, respectively, were the highest ever observed at those points in April.

The lowest temperatures of the month were observed on the 1st over all districts from the Mississippi River eastward, and over a few States to the westward. In the Great Plains and to the westward the coldest days were mainly in the first decade. The lowest observed, −34°, occurred in northern Michigan, and a reading of −24° was reported from northern New York. Freezing temperatures or lower were reported from every State except Florida, where 34° was the lowest observed.

The continued cold over the Great Lakes resulted in an unusual accumulation of ice in the more northern portions, and the opening of navigation at the Soo was much delayed.

PRECIPITATION.

The precipitation of April, as a whole, was sufficient over most of the country, and was comparatively large in the central Plains and in almost all districts to southward and southeastward. Unusually heavy rainfall occurred in southeastern Texas, central Louisiana, and central and northern Mississippi, Brookhaven, in the last-named State, measuring more than 16 inches. Substantially all of Texas, save the vicinity of the Rio Grande, and nearly all districts to southward of the lower Missouri and of the Ohio and Potomac Rivers had more than normal rainfall, except from central Florida northward and northeastward to the vicinity of Hatteras there was a marked shortage. However, the southern portion of Florida and some areas near the central east coast received marked relief from the dry conditions that had so long prevailed. Near Chesapeake and Delaware Bays the amounts were well above normal, likewise in most of New England, particularly in central Maine, where heavy rains near the end of the month, with the rapid melting of the remainder of the winter's snowfall, caused serious floods. In northern Michigan also there were considerable floods late in the month, the rapid melting of deep snows, when a marked rise of temperature set in, being the main factor. To northward of the Potomac and Ohio Rivers the month's precipitation usually fell short of the normal by slight to moderate amounts; but from southeastern Iowa eastward to northwestern Ohio and southern Michigan there was a notable shortage, and rain was considerably needed there when the month closed.

In the western half of the country the distribution was more uneven than usual, and the month's totals were less than normal in western South Dakota, central and southern Colorado, western New Mexico, and southern Arizona; also in northern and western Montana, nearly all of Washington, and much of Oregon and Idaho. In California, on the other hand, the month was considerably the wettest April of the 27 for which State-wide averages have been computed, the excess being most notable in the central portion, and being of vast benefit in overcoming the results of the shortages in February and March. The excess of precipitation was felt to eastward, in nearly all parts of Nevada and Utah and the upper Snake River drainage basin.

SNOWFALL.

The snowfall of April occurred chiefly in the early portion of the month. It was about average in amount in the northeastern portion, including the region of the

lower Lakes, but it was considerably more than average in Wisconsin and upper Michigan, where most of it came during two storms of the first week. In Ohio and Indiana and in Kansas and western Missouri the southern limit of the snowfall was unusually far to the north for April.

In the elevated portions of the Western States conditions varied greatly; but the snowfall was light in most mountain portions of Arizona and New Mexico and of many of the more northern States. On the other hand, the California, Nevada, and Utah mountain areas had much more than the normal amounts for April, especially the Sierra regions between 40° and 36° latitude. Here Glacier Point, Calif., recorded no less than 113 inches fall during the month.

The snow remaining at high levels at the end of April did not give promise of abundant stream flows next summer in Arizona and in most parts of the North Pacific States. In California and Nevada the April falls considerably improved the prospects, yet they were mainly a little below average; the April snowfall did not pack well, and the late summer water supply is likely to be inadequate. In Utah, Idaho, and the Rocky Mountain States the prospects for stream flow were usually rather better than the average.

RELATIVE HUMIDITY.

The distribution of the relative humidity, like the precipitation, varied greatly at near-by points, but on the whole the monthly averages were below normal from the middle Mississippi Valley eastward and northeastward to the Atlantic coast. Over other districts the averages were mainly above normal, with the greatest excesses in the southern portions of the Great Plains and Plateau regions, and locally in central California.

SEVERE LOCAL STORMS, APRIL, 1923.

The table herewith contains such data as have been received concerning severe local storms that occured during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau.]

Place.	Date.	Time.	Width of path (yards).	Loss of life.	Value of property destroyed.	Character of storm.	Remarks.	Authority.
Chappells, S. C.	4					Wind	School building wrecked	Official, U. S. Weather Bureau.
Wake-Nash county line, N. C.	4	6 p. m.			$100,000	Tornado	25 small buildings damaged or completely destroyed, also about 40 tobacco barns and outhouses; many large trees uprooted; 2 persons injured.	Do.
Cass County, Tex. (northeast part of).	4	P. m.	100		35,000	do	About 20 buildings wrecked	Do.
Alexandria and Pineville, La.	4	6 p. m.		14	500,000	do	About 142 buildings damaged, and 60 persons injured; path 3 miles long and several hundred yards wide.	Times-Picayune (New Orleans, La.); Post (New York).
El Dorado, Ark., and vicinity.	4	5 p. m.				Wind and hail	Several farmhouses blown from foundations, 1 demolished; 1 man injured.	Southwestern American (Fort Smith, Ark.).
Yazoo City, Miss.	4	P. m.		2		Wind	No property damage reported	Times-Picayune (New Orleans, La.).
District of Columbia and adjacent Maryland.	5	3 p. m.	200		100,000	Tornado	4 persons hurt; 7 houses in Silver Springs and Avenel demolished; many other houses and outbuildings damaged; hundreds of trees uprooted, broken, or torn; path 11 miles long.	Official, U. S. Weather Bureau.
Philadelphia, Pa., and adjacent districts.	5					Wind and rain	A score of houses partly wrecked in city; other serious damage in nearby counties.	Do.
Hunterdon County, N. J.	5					do	Thousands of dollars property damage	Do.
New Castle County, Del.	5					Thunderstorm	Farmhouses, barns, telephone and telegraph poles damaged.	Do.
Magnolia Springs, Tex. (vicinity of).	6	8 p. m.			3,000	Wind	Crops and buildings damaged	Do.
Rochester, N. Y., and nearby counties.	8	P. m.				Wind and rain	Heavy property damage; County Agricultural Society and farmers sustain heavy losses; big dining hall demolished.	Post Express (Rochester, N. Y.).
Meridian, La.	12	4:30 a. m.				Tornado	15 houses wrecked, 45 others damaged; 6 persons injured.	Item (New Orleans, La.); Shreveport Journal (La.).
Cullman, Ala.	12	P. m.				Wind	3 persons injured, several residences and barns blown down, and scores of animals killed; all wire services paralyzed.	Inquirer (Owensboro, Ky.).
Lafourche, La., and vicinity.	13	A. m.	200	2	100,000	Tornado	Many houses wrecked and 25 persons injured	Times-Picayune (New Orleans, La.).
Anniston, Ala.	13	9:30 a. m.				Wind	Several houses and barns unroofed; trees uprooted and wires damaged.	Anniston Star.
Greenville, S. C.	13	4 p. m.			1,000	Tornado	Small dwellings destroyed	Official, U. S. Weather Bureau.
Augusta, Ga.	13	P. m.				Wind and rain	Several stores damaged; trees, plate-glass windows, and wires suffer most from wind; car traffic held up.	Greenville News (S. C.).
Orange, Tex.	20	4 p. m.				Wind	Portion of roof of lumber shed blown off	Official, U. S. Weather Bureau.
Central Illinois	21	A. m.				do	Considerable damage done to trees, residences, poles, wires, and outhouses.	Do.
Chicago, Ill.	21			1		do	Some property damage	Do.
Ludington, Mich. (5 miles southeast of).	21	1 p. m.	200		1,000	do	High winds damage trees, buildings, etc.; path 5 to 10 miles long.	Do.
Randolph, Utah	22					do	Chimneys, haystacks, and some roofs damaged	Do.
Donaldson, Tenn.	23	Noon				Thunderstorm	Schoolhouse damaged and about 30 children injured.	Do.
Barneston, Kans. (near).	23	P. m.		2		Tornado	1 home totally destroyed; path 4 miles long	Wichita Eagle (Kans.).
Burkburnett, Tex. (vicinity of).	24	8-9 p. m.			25,000	do	5 residences and 6 oil derricks destroyed	Official, U. S. Weather Bureau.
Henrietta, Tex. (vicinity of).	24	7:20-8:20 p. m.	1,760		200,000	Wind	Crops and buildings severely damaged; storm was accompanied by hail; path 15 miles long.	Do.
Syracuse, Kans. (2 miles southwest of).	27	2 p. m.		1		do	Teacher of school killed and 2 children injured	Wichita Eagle (Kans.).
Mobile County, Ala.	27				5,400	do	Considerable property damaged; storm was accompanied by hail.	Official, U. S. Weather Bureau.
Dardanelle and Russellville, Ark. (country surrounding).	28				200,000-300,000	Wind and rain	Houses unroofed and crops damaged; 1,500 acres of cotton will have to be replanted; heavy hail accompanied storm.	Do.
Waltersville, Miss.	28					Wind	Damage principally to residences, telephone and trolley lines, and to an industrial plant.	Do.
Little Island Coast Guard Station, Va.	29	12:01 a. m.				Tornado	Station, 3 residences, and several outbuildings demolished; 600 yards of telegraph line blown down.	Do.

STORMS AND WEATHER WARNINGS.

By EDWARD H. BOWIE, Supervising Forecaster.

There were issued regularly during the month, the daily forecasts of weather, temperature, and winds for the various State forecast units, winds and weather for the water areas off the Atlantic and Pacific coasts and for the Great Lakes, the Gulf of Mexico, and the western part of the Caribbean Sea, aviation forecasts for the several zones and for the Army airways; and in addition to these daily issues, warnings of frost and freezing temperatures for the States were disseminated as required. Moreover, storm warnings for the coastal regions and the Great Lakes and special advices concerning weather and temperature changes for the continent were issued as required.

The month of April was not particularly abnormal from a forecasting standpoint, except as to the frequency of frost warnings and the occurrence of late frosts. Forecasts of snows in the Northern States were also more numerous than is usual in the month of April.

WASHINGTON FORECAST DISTRICT.

In the Washington Forecast District frost warnings were issued on a number of days, the more important being on the 5th for Tennessee and the extreme north portions of Alabama and Mississippi; on the 8th for freezing temperature or frost for the lower Great Lakes region, the Ohio Valley, the Middle Atlantic States, Tennessee, and the north portions of the east Gulf States; on the 9th for nearly the same areas and the north portions of Georgia and South Carolina; on the 16th for the Atlantic States as far south as western North Carolina and the Ohio Valley and northern Tennessee; on the 17th for the Middle Atlantic States, the Ohio Valley, Tennessee, and the north portions of Alabama and Mississippi; on the 18th for nearly all parts of the Washington Forecast District, the South Atlantic and Gulf coasts excepted: on the 24th and 25th for the lower Great Lakes region, the Upper Ohio Valley, and the Middle Atlantic States; and on the 30th for the upper Ohio Valley, the lower Great Lakes region, and the North Atlantic States.

Warnings of winds more or less dangerous to navigation on coastal waters were issued as follows during the month: On the 9th at 9:30 p. m., southwest storm warning were displayed on the Atlantic coast at and between the Virginia Capes and Eastport, Me.; on the 11th, an advisory warning of strong winds was issued for the North Atlantic coast; on the 12th, small craft warnings were displayed over the Mobile and Pensacola storm-warning sections; and on the 13th and 14th storm warnings were displayed on the Middle Atlantic and southern New England coasts and on the 15th the display was extended northward to Eastport, Me.; on the 20th, the small-craft warning was displayed on the east Gulf coast west of Tampa: on the 23d, northwest storm warnings were displayed on the Atlantic coast at and between New London, Conn., and Provincetown, Mass.; on the 28th, small-craft warnings were displayed on the Atlantic coast at and north of Cape Hatteras and at 9:30 p. m. of the same day the warnings were changed to southeast storm on the New England coast; on the 29th, small-craft warnings were displayed on the South Atlantic coast at and between Wilmington, N. C., and Jacksonville, Fla.

CHICAGO FORECAST DISTRICT.

Over most of the district the month was cooler than usual, but not markedly so except in the eastern portion of Upper Michigan, where the temperature averaged 5° below the normal. A feature of the temperature conditions was the rapid alternations from day to day during the first half of the month. The precipitation was deficient in most sections, especially in the middle Mississippi Valley, but more than the normal amount occurred in Montana, the western portions of North Dakota and Kansas, northwestern Iowa, northern Lower Michigan, and the extreme southern portions of Illinois and Indiana.

So far as the occurrence of conditions calling for special warnings is concerned the month was rather uneventful.

Cold-wave warnings.—The only cold-wave warnings issued were those on the 6th for Upper Michigan and extreme northern Lower Michigan. In the main, these warnings were verified, but the cold wave was of little importance. On the 7th a decided fall in temperature occurred over most of the Central Plains States and middle Mississippi Valley, the fall attaining the proportions of a cold wave in portions of eastern Kansas and a small area in northwestern Missouri.

Live-stock warnings.—Live-stock warnings were issued on the 6th for southeastern Wyoming and the western portions of South Dakota and Nebraska, and again on the 22d for western Nebraska. In neither case, however, did the ensuing conditions become severe.

Frost warnings.—Owning to the lateness of the season the advance of vegetation was decidedly backward and the frosts of the month were of little economic importance. At the opening of the month frost warnings were required only in southeastern Kansas, but as the month advanced this area spread slowly northward, so that by the close Kansas, Nebraska, Missouri, and most of Iowa, Illinois, and Indiana were included. Warnings of frost or freezing temperature were issued on the following dates: 5th, 7th, 8th, 9th, 11th, 13th, 14th, 15th, 16th, 17th, 20th, 21st, 23d, 24th, and 26th.

Storm warnings.—The storm-warning season on the Great Lakes was opened on the 21st except in the case of Lake Superior, where the opening date was deferred to May 1. These dates are later than usual as a result of the severe character of the latter part of the winter, together with the backwardness of the spring season. Generally speaking, the accumulation of ice in the Great Lakes was the heaviest in years.

Preceding the opening of the storm-warning season advisory warnings were issued for Lake Michigan on the 1st, 7th, 11th, 13th, 15th, 19th, and 20th. The disturbance of the 7th–8th attained some intensity, and moderate gales occurred over most of the Lake. Farther east on the lower Lakes the storm became more severe, fresh to strong gales being reported. On the morning of the 20th a trough of low pressure of considerable depth was advancing eastward across the Plains States, and an advisory warning for strong southerly winds was issued for Lake Michigan. By the following morning the disturbance had developed still further, with a definite center over Iowa and a barometer reading of 29.24 inches. Accordingly, southwest storm warnings were issued for Lakes Michigan, Huron, and Erie, and later,

at 4 p. m., extended to Lake Ontario. The center of the disturbance moved slowly northeastward, but by the morning of the 22d the storm had almost lost its identity and appeared to be dissipating over northern Michigan. Verifying velocities were attained over extreme southern Lakes Michigan and Huron and over portions of Lakes Erie and Ontario. The remainder of the month was without any storm activity that required the issuance of warnings.—*C. A. Donnel.*

NEW ORLEANS FORECAST DISTRICT.

Small-craft warnings were displayed on the Texas and Louisiana coasts on the 12th for a disturbance of moderate intensity, which moved northeastward from the lower Rio Grande Valley and was attended by shifting winds which reached moderate gale force at times.

On the 19th a V-shaped trough of low pressure extended into west Texas and northern Mexico and was advancing eastward. Southeast storm warnings were ordered displayed on the Texas coast at 8:40 p. m. Winds of verifying velocity occurred during the night. Small-craft warnings were displayed on the Louisiana coast on the 20th and were justified.

Small-craft warnings, displayed on the Texas coast on the 23d, were justified.

On the 30th, with conditions generally similar to those of the 19th but with smaller barometric gradient, southeast storm warnings were ordered displayed on the Texas coast at 8:40 p. m. A 40-mile wind from the southeast was reported the next morning from Galveston, Tex.

Frost forecasts for the northern portion of the district, or some part thereof, were issued on the 5th, 7th, and 8th and were justified. Forecasts of frost, issued on the 14th 15th, and 24th, were not so successful, the temperatures not being quite low enough for frost.—*R. A. Dyke.*

DENVER FORECAST DISTRICT.

Low-pressure areas occupied some portion of the Denver Forecast District on 26 days during April. Four anticyclonic areas appeared on the northeastern slope of the Rocky Mountains during the month, and one of these, during the latter part of the month, persisted for nearly a week.

A moderate cold-wave warning was issued for extreme northeastern Colorado on the evening of the 5th, an anticyclonic area having appeared on the northeastern slope, with a sharp rise in pressure in western Montana and over the Dakotas. The temperature fell 28° at North Platte on the evening of the 6th and temperatures as low as 26° occurred along the eastern border of Colorado the following morning. On the morning of the 7th low-pressure areas of marked intensity were central in Iowa and southwestern Colorado, with moderately high barometric readings in Montana accompanied by temperatures ranging from 6° to 20° above zero. A cold wave occurred at Modena, without warnings, following the passage of a secondary depression over that locality. Freezing-temperature warnings were issued for Utah, Colorado, northern Arizona and northern New Mexico, with a moderate cold wave in central Colorado and possibly frost in southern Arizona. Freezing temperatures occurred throughout the area for which these warnings were issued, but the cold-wave warning for central Colorado was not verified as the HIGH moved southeastward to Kansas and the temperature fall in southern Arizona was not sufficient for the formation of frost. Low pressure prevailed on the southeastern slope on the morning of the 13th, with an extensive high-pressure area over the North Pacific states. Warnings of freezing temperature were issued for northeastern Arizona and frost or freezing temperatures for Colorado, Utah, and northern New Mexico. Frost or freezing temperatures occurred in the greater part of the area. The HIGH occupied the northern Rocky Mountain region and the eastern slope on the 14th and warnings of frost in northern and eastern New Mexico and local frost in Colorado were issued. Frost was reported in the greater part of the area, with frost temperatures as far south as the Mexican border. As the HIGH still occupied the Rocky Mountain region on the 15th local frost warnings were repeated for Colorado and northern New Mexico. Frosts were again reported in Colorado, but the development of a LOW in the Southwest was attended by cloudiness in New Mexico.

On the morning of the 20th low-pressure areas of marked intensity occupied Manitoba and the Texas Panhandle, with relatively high pressure in the middle Plateau region. Warnings of freezing temperature were issued for Colorado and New Mexico. Freezing temperature occurred in eastern Colorado and frost temperatures in parts of New Mexico. At 8 a. m. on the 22d a LOW of marked intensity was central in northeastern Arizona, with an anticyclonic area on the northeastern slope. Live-stock warnings were issued for Utah and northern and western Colorado, freezing-temperature warnings for northern New Mexico and northeastern Arizona and possibly frost in southern Arizona. Freezing temperatures occurred accompanied by heavy precipitation in parts of Colorado. Frost was reported at Phoenix, a temperature of 46° at Yuma and a killing frost at Santa Fe. Freezing-temperature and frost warnings were issued on the morning of the 23d for Colorado, New Mexico, Utah, and northern Arizona and frost in southern Arizona as the pressure was increasing throughout the district. Freezing temperature or frost prevailed, except in New Mexico, where cloudiness developed with rising temperature owing to relatively low pressure in southern Arizona. Frost or freezing-temperature warnings were repeated on the morning of the 24th for Colorado, Utah, and eastern New Mexico. Owing to the development of the southwestern LOW the temperature rose and freezing weather was reported only in localities in Utah and Colorado. On the morning of the 30th an area of low pressure of marked intensity, that had its inception in the Plateau region, was central in Colorado, followed by rising pressure in the Plateau region. Warnings of freezing temperature or frost were issued for eastern and southern Utah, freezing temperature in western Colorado, northern New Mexico, and northeastern Arizona, and possibly frost in southern Arizona. The warnings were justified, except in southern Arizona, where the fall in temperature was small owing to a slight barometric depression in southwestern Arizona.—*Frederick W. Brist.*

SAN FRANCISCO FORECAST DISTRICT.

Following a protracted dry spell in March, the month of April was ushered in with good rains that lasted intermittently till the 10th. Another rainy spell began began on the 17th and continued until the 21st, after which fair weather generally prevailed. The low-pressure areas causing the early rains came from the ocean;

while those causing the rains near the middle of the month were extensions of ocean storms combined with sudden new developments taking place over the land.

Frost warnings were issued for some one or more parts of the San Francisco Forecast District on 13 days and they were for the most part verified. Storm warnings were issued on the 2d, 4th, 17th, 18th, and 20th, the first three dates being for local storms between San Francisco and Eureka. That on the 18th was for expected local winds at Tatoosh Island, and those on the 20th were for a general storm along the North Pacific coast. Small-craft warnings were ordered at all North Pacific seaports on the 30th. It is believed all the storm warnings were justified and, in consequence, were of benefit to the marine interests.

Live-stock warnings were issued on the 16th for northern Nevada, Idaho, eastern Oregon, and eastern Washington. This was an especially good warning, as it was followed by a sudden and marked drop in temperature, and at the same time cold rains occurred at practically all of the places where the warnings where received. —*E. A Beals.*

RIVERS AND FLOODS.

By H. C. FRANKENFIELD, Meteorologist.

The most severe and destructive floods of the month occurred in New England, and particularly in Maine and New Hampshire. Much of the abnormal snowfall of the preceding winter remained in the northern woods, but the high temperatures of the closing days of the month caused it to melt rapidly and add its large increment to the run-off from the heavy rains of April 28 and 29 and the showers of April 30. The State of Maine suffered heavily, as will be seen in the report below by Mr. Edward P. Jones, meteorologist in charge of the Weather Bureau Office, Portland, Me:

The Maine flood owed its inception to the unprecedented snowfall of the past winter which, by reason of the unfrozen condition of the soil had caused the latter to become virtually saturated. The high temperatures of late April rapidly melted the large quantity of remaining snow, so that the accompanying heavy rains soon brought about a great flood. The absence of a sufficient number of storage basins was also a contributing factor, while another was that of the high tides that backed up the larger rivers at their mouths.

The flood extended over most of the State, and did the greatest damage along the Kennebec River, although it did not exceed that caused by the flood of December 16, 1901.

Extreme western Maine was free from serious flood conditions, while Aroostook County reported the worst flood on record.

The Moosehead storage prevented any great discharge from the east branch of the Kennebec, the flood flows coming almost entirely from Dead, Carrabassett, and Sandy Rivers, and becoming most severe at Fairfield, Waterville, Augusta, and Gardiner, although the entire Kennebec Valley suffered seriously.

The rivers began to rise April 28 and by night the Kennebec, Union, Machias, Penobscot, Piscataquis, and St. Croix were pressing against the dams and bridges along their courses. At 3 a. m. Sunday, April 29, the Kennebec overflowed its banks at Augusta and by 7 p. m. there was a 10-foot flow over the dam. The normal flow is about 3 feet.

The crest at Augusta was reached at 4 p. m. April 30 and the water fell below flood stage on Friday, May 4.

At Skowhegan the flow over the dam during the crest of the flood was 90,000 cubic feet per second, quite near the record established in 1901. At Gardiner the flood stage was reached at 2 a. m. April 29 and the crest stage at 3 a. m. May 1. The river fell below flood stage at 10 a. m. May 3.

The Androscoggin River has a fine storage basin near its source, but it drains a large area and the run-off when the snow commenced to melt caused the river to rise to danger point, eventually reaching the highest stage since the 1896 freshet.

The river at Rumford overflowed its banks April 29, reached the highest point April 30, and fell below flood stage at 10:30 p. m. May 3.

At Lewiston and Auburn the flood stage was reached at 10 a. m. April 29, the peak at 1 a. m. May 1, and the river fell below flood stage May 3. The highest registration of water flowing over the dam at 1 a. m. May 1 was 7 feet and 4½ inches.

The Penobscot is better controlled than any other river in Maine. If this river had been left to its own devices in the recent flood, as was the Kennebec, the city of Bangor would have been almost entirely overflowed. Only the Great Northern Paper Co. storage dams saved the city.

The rush of waters which smote Oldtown, Orono, and Bangor and other cities and towns in this region with such disastrous force came from the East Branch, the Seboeis River, and other streams in that territory tributary to the Penobscot. The dams there were inadequate to withstand the flood. Freshet alarm was sounded on the 28th and by 6 a. m., the 29th, the river at Oldtown, Orono, and Bangor reached flood stage.

Bangor was menaced as it had not been in 20 years by the waters of the Penobscot and the Kenduskeag, a tributary which flows through the business center of the city. The flood crest here occurred at 12:30 a. m. May 2, and the river fell below flood stage at 12:30 a. m. May 3.

At Dover and Foxcroft on the Piscataquis River the flood stage occurred April 28, crest on April 29, and the river did not fall below flood stage until May 8.

At Ellsworth on the Union River there were two flood crests one on April 30 and the other at 10 p. m. May 2, the latter due to the collapse of the large storage dam on the afternoon of the 2d.

High water levels were established all along the St. Croix and its tributaries.

At Fort Fairfield, on the Aroostook River, a tributary of the St. John, the flood stage occurred at 4 a. m. April 30, crest at 5 p. m. May 2, and the river did not fall below flood stage until May 5.

The following dams were swept out; Great Northern Paper Co's. dam at Lake Hoxie; Marshfield and East Machias dams, Milltown Bulkhead at North Anson, Hodgdon dam at Meduxnekeag, Ebeemee Pond dam, Katahdin Iron Works structure on Pleasant River, and the large dam at Ellsworth.

Activities in Aroostook County were paralyzed, its highways were under water, its transportation service suspended, and many families homeless. The waters were still at freshet height on May 2.

The losses, exclusive of those suffered by the railroads, were about $3,000,000, of which probably two-thirds was caused by the Penobscot River and its tributaries.

In the Merrimac Valley of New Hampshire and eastern Massachusetts there was less snow to melt than in Maine, but the rainfall was heavier. The river, however, did not rise above flood stage, except in localities, and the damage done was small.

The flood in the Connecticut River Valley was not so severe, as the total rainfall was somewhat less than in Maine and New Hampshire, and the amount of snow on the ground also less. The river reached a stage of 22 feet at White River Junction, Vt., at 2 p. m. April 30, or 9 feet above flood stage, and 20.4 feet at Hartford, Conn., at 2:30 p. m. May 2, or 4.4 feet above flood stage.

Flood warnings for the entire valley were issued on April 29 and 30. Not much damage occurred, although considerable inconvenience resulted in several places.

Earlier in the month there was another flood caused by fairly heavy rains in conjunction with the break-up of the ice. It was the usual spring freshet, and caused the usual minor damage to highways, railroads, etc. Unfortunately one death occurred at South Charlestown, N. H., where a hunter was drowned after the overturning of his canoe.

The crest stages of this flood were considerably lower than those of the late April and early May flood. The usual warnings were issued.

The same general conditions that attended the earlier Connecticut flood prevailed over the Hudson River drainage basin, but in less pronounced form, and the crest stages in the vicinity of Troy and Albany, N. Y., early on April 7, were from 2 to 5 feet above the flood stages. Warnings were issued on the morning of April 6, and were well verified by the subsequent occurrences. There were no losses of consequence.

In the extreme upper Susquehanna basin of New York there were some bankful stages, but without incident.

There were minor overflows in the rivers of North Carolina about the middle of the month which were ac-

curately forecast and there was no damage, although farming operations were somewhat delayed. The Santee River of South Carolina remained in flood until the last two days of the month. It had been in flood since March 1, 1923.

At the beginning of April the Tombigbee River at Demopolis, Ala., was 11.6 feet above the flood stage of 39 feet, and it did not fall below this stage until the morning of April 28. It fell slowly after a slight secondary rise on April 5 and 6, to a stage of 38.2 feet on April 13, when heavy rains over the drainage area of the Black Warrior River inaugurated another rise to a crest stage of 46.2 feet on April 19; meanwhile the Black Warrior River had risen from 17.6 feet on April 12 to 48.5 feet on April 15, or 2.2 feet above flood stage. Warnings were issued for both rivers. A large area of lowlands below the mouth of the Black Warrior remained flooded throughout the month, and a small section of Black Warrior bottoms were inundated. No damage statistics are yet available.

There were also floods in the Pascagoula and Pearl systems of Mississippi due to excessive rains on April 3 and 4. In the Chickasawhay and Leaf Rivers the crest stages were only moderately high, but, as farming and lumbering operations had been at a standstill since March 15 on account of previous floods, the resulting losses, actual and prospective, were considerable. In the Pearl River the floods were of a dangerous character. They began on March 23, and did not cease from Jackson southward until April 28. The crest stage of about 30.5 feet at Jackson on April 6 was 10.5 feet above the flood stage, while at Columbia the crest on the same date was 8.5 feet above the flood stage of 18 feet. The West Pearl River of Louisiana was also in flood during the same period, and continued so at the close of the month. Warnings were first issued on March 23, after a rainfall of more than 4 inches over the upper drainage basin, and as often thereafter as was necessary.

Complete figures regarding loss and damage were not obtainable, but the reported total approximated $400,000, of which about $155,000 was in prospective crops. The value of property reported saved through the warnings was $19,500.

The upper Mississippi River was not in flood at any point during the month. The Ohio River flood of March continued down the lower river, the flood stage of 34 feet at New Madrid, Mo., having been reached on March 18. This flood began in the Ohio River below the mouth of Green River on March 14, the crest of 37.8 feet passing Evansville, Ind., on March 20. At Cairo, Ill., the maximum stage of 46.7 feet occurred on March 21 and 22, the crest finally reaching New Orleans, La., on April 15, or 25 days from Cairo. The time from Cairo to Vicksburg, Miss., was 19 days, apparently about 5 days longer than would have been required had not heavy and very general rains fallen on April 3 and 4 over the immediate drainage basin. Additional heavy rains from Vicksburg to Baton Rouge, La., on April 11 and 12, caused an additional rise and a consequent further delay of about 4 days in the arrival of the crest at Natchez, Miss. Below Natchez there was a marked shortening of the time interval, both on account of the heavy rains and of the flood waters from the Ouachita and Red Rivers, which arrived at the time of the Natchez crest, so that between Natchez and New Orleans, a distance of 259 miles, the interval between crests was only 1 day instead of the usual week or so. It appears then that the decreased time below Natchez was just about compensated for by the increased time between Vicksburg and Natchez.

In accordance with the prevailing practice this flood was excellently forecast, both in the main stream and in the Green, St. Francis, Ouachita, and Red Rivers, which were contributory to the general floods. The crest stages, etc., will be found in the usual table at the end of this report.

There were no preventable losses. There was some damage to railroads and highways, and farming, logging, and levee work were much hampered and delayed.

Planters were greatly benefited by the daily forecasts, and one large owner in the lower White River Valley of Arkansas stated that without the warnings of the Weather Bureau he would be unable to operate.

The reported total of loss and damage was $325,000, of which $75,000 was in prospective crops, and $200,000 due to suspension of business. The reported value of property saved in the Memphis district through the warnings was $200,000.

The break-up of the ice in the Wisconsin River began about the middle of the month, and moderate flood stages occurred at several points. No warnings were issued.

The Illinois River which had been in flood at the beginning of the month fell steadily thereafter. There was no damage.

Moderate floods occurred in the rivers of eastern Texas at various times during the month. Warnings were issued whenever and wherever necessary, and the reported total of loss and damage, $124,000, was small, considering the large area involved. About 27,000 acres of land, mostly grazing land, and 800 acres of crop lands were overflowed along Trinity River from above Bridgeport to below Trinidad. On the other hand no loss of live stock in the lowlands occurred, and the reported value of property saved by the warnings was $190,000.

There were no other floods except local ones in the lower Guadalupe River of Texas, and in the upper Llano River, a tributary of the Colorado River of Texas.

Flood stages during April, 1923.

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
ATLANTIC DRAINAGE.					
Connecticut:		*Feet.*		*Feet.*	
White River Junction, Vt.	13	5	14	17.9	9
Do	13	23	27	17.0	24
Do	13	29	(1)	20.5	30
Holyoke, Mass.	9	7	8	9.4	7
Hartford, Conn.	16	6	14	22.0	8
Do	16	30	(1)	17.4	30
Hudson:					
Albany, N. Y.	12	6	8	13.9	6
Unadilla:					
New Berlin, N. Y.	8	6	6	10.5	6
Roanoke:					
Weldon, N. C.	30	14	15	33.0	14
Neuse:					
Neuse, N. C.	15	15	17	16.3	16
Smithfield, N. C.	14	15	18	15.9	17
Cape Fear:					
Elizabethtown, N. C.	22	16	17	24.8	16
Santee:					
Rimini, S. C.	12	(2)	2	13.0	1
Do	12	5	23	13.9	10
Do	12	27	27	12.1	27
Ferguson, S. C.	12	(2)	28	13.3	10
EAST GULF DRAINAGE.					
Apalachicola:					
River Junction, Fla.	12	(2)	3	14.0	1
Blountstown, Fla.	15	(2)	11	17.6	1
Do	15	16	18	15.2	17
Tombigbee:					
Lock 4, Ala.	39	(2)	12	50.6	1
Do	39	14	27	46.2	19
Black Warrior:					
Lock 10, Ala.	46	14	15	48.2	15

[1] Continued into May.

[2] Continued from March.

Flood stages during April, 1923—Continued.

River and station.	Flood stage.	Above flood stages—dates. From—	To—	Crest. Stage.	Date.
EAST GULF DRAINAGE—continued.					
Chickasawhay:		*Feet.*		*Feet.*	
Enterprise, Miss.	21	6	7	24.6	6
Shubuta, Miss.	27	7	10	28.9	2
Leaf:					
Hattiesburg, Miss.	19	6	7	20.0	6
Pearl:					
Jackson, Miss.	20	(2)	28	30.5	6
Columbia, Miss.	18	(2)	26	26.5	6
West Pearl:					
Pearl River, La.	13	(2)	(1)	16.9	9
GREAT LAKES DRAINAGE.					
Pine:					
Alma, Mich.	6	6	6	6.2	6
Do.	6	8	8	6.1	8
MISSISSIPPI DRAINAGE.					
Mississippi:					
New Madrid, Mo.	34	(2)	2	34.6	1
Memphis, Tenn.	35	(2)	4	35.8	1
Helena, Ark.	44	(2)	7	45.4	1
Arkansas City, Ark.	48	(2)	10	49.4	4–7
Greenville, Miss.	42	6	7	42.0	6–7
Vicksburg, Miss.	45	(2)	19	48.0	9–10
Natchez, Miss.	46	3	21	48.7	14
Baton Rouge, La.	35	4	29	38.8	15
Donaldsonville, La.	28	5	27	30.6	16
New Orleans, La.	17	8	23	18.1	14–16
Wisconsin:					
Merrill, Wis.	11	21	23	11.9	21
Knowlton, Wis.	12	20	24	16.0	22
Spirit:					
Tomahawk, Wis.	14	21	22	14.7	22
Illinois:					
Peru, Ill.	14	(2)	2	14.1	1
Henry, Ill.	7	(2)	20	9.0	1–2
Peoria, Ill.	16	(2)	1	16.5	1
Havana, Ill.	14	(2)	1	14.1	1
Beardstown, Ill.	12	(2)	17	14.6	1
St. Francis:					
Marked Tree, Ark.	17	(2)	15	18.7	1–3
North Canadian:					
Woodward, Okla.	3	29	29	3.6	29
Petit Jean:					
Danville, Ark.	20	29	(1)	22.3	30
Black:					
Black Rock, Ark.	14	(2)	2	16.0	1
Do.	14	5	8	16.1	5
Yazoo:					
Yazoo City, Miss.	25	(2)	(1)	30.3	25
Tallahatchie:					
Swan Lake, Miss.	25	(2)	(1)	28.8	8-10,13-15
Atchafalaya:					
Simmesport, La.	41	7	7	41.0	7
Do.	41	9	26	43.3	16–17
Melville, La.	37	4	(1)	39.9	16–17
WEST GULF DRAINAGE.					
Sabine:					
Logansport, La.	25	6	14	27.1	8
Bon Wier, Tex.	20	(2)	26	22.3	5,15
Orange, Tex.	4	4	(1)	5.8	16–17
Neches:					
Rockland, Tex.	22	13	20	27.6	15
Beaumont, Tex.	7	(2)	5	7.9	2–3
Do.	7	8	10	7.9	8
Do.	7	12	29	11.2	16
Trinity:					
Bridgeport, Tex.	25	26	27	25.7	26
Dallas, Tex.	25	26	(1)	32.2	29
Trinidad, Tex.	28	28	(1)	32.1	30
Liberty, Tex.	25	(2)	6	26.8	3–4
Do.	25	14	23	27.6	20
Brazos:					
Freeport, Tex.	4	17	17	5.8	17
Guadalupe:					
Victoria, Tex.	16	16	16	17.0	16

[1] Continued into May. [2] Continued from March.

MEAN LAKE LEVELS DURING APRIL, 1923.

By UNITED STATES LAKE SURVEY.

[Detroit, Mich., May 7, 1923.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes.[1] Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during April, 1923:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sea level at New York	601.39	579.18	571.31	245.33
Above or below—				
Mean stage of March, 1923	−0.06	+0.20	+0.33	+0.59
Mean stage of April, 1922	−0.05	−0.78	−1.01	−0.73
Average stage for April, last 10 years	−0.43	−1.25	−1.17	−1.06
Highest recorded April stage	−1.30	−4.05	−2.87	−3.10
Lowest recorded April stage	+0.85	−0.04	+0.05	+0.49
Average relation of the April level to—				
March, level	.....	+0.40	+0.70	+0.70
May, level	.....	−0.30	−0.40	−0.30

[1] Lake St. Clair's level: In April, 574.14 feet.

EFFECT OF WEATHER UPON CROPS AND FARMING OPERATIONS, APRIL, 1923.

By J. B. KINCER, Meteorologist.

The temperature for the month of April averaged near the normal in practically all sections of the country, but warmth in different portions of the month varied greatly and on the whole temperature conditions were unfavorable for agricultural interests. Unusually low temperatures for the season prevailed during the first of the month when subzero readings were reported from points in the northern Lake region and freezing extended to the central portions of the east Gulf States. Precipitation was frequent and heavy in the South, except in the south Atlantic districts, and was much above normal in California. Somewhat less than the normal amount was received from the Ohio and central Mississippi Valleys northward. Sunshine was scanty in most sections east of the Rocky Mountains, especially in the upper Mississippi Valley and the west Gulf area.

The cool, cloudy weather during the first half of the month in the central and northern States east of the Rocky Mountains retarded vegetative development considerably, while frequent rains in the South delayed field work in that section and the unseasonable cold caused delay in farm operations to the northward.

The latter half of the month was much more favorable for agricultural interests in the interior and northern States, as warmer weather and more sunshine prevailed. Winter wheat showed some improvement in the Ohio Valley States, but the crop was backward and growth slow, because of the cool spring, and moisture was needed at the close of the month in much of this area as well as in the Lake region. Generous rains in Nebraska during the week ending April 24 greatly benefited fall-seeded grains, while the long drought in western Kansas was effectually broken during the following week. Much better weather for field work prevailed in the spring-wheat States during the latter part of the month, although it continued too wet in a few localities. Conditions were more favorable also for seeding oats and this work was completed or well advanced at the close of the month in the later, northern districts.

The preparation of soil for corn and planting made slow progress until the last two weeks of the month when better advance was possible. Much corn ground was prepared and some planting was done in the principal producing areas. The month was generally unfavorable in the Cotton Belt owing to frequent rains and wet soil. On the whole cotton made fair progress in Texas and planting

was well advanced at the close of the month, except in the wetter areas. Planting made better progress in the central and eastern portions of the belt the latter part of the month, but was generally backward.

Conditions were mostly favorable for pastures and ranges except that grass started slowly in most central and eastern portions of the country because of low temperatures. Ranges were needing moisture in the Southwest and rain was needed from the Lake region eastward, but the generous precipitation in the central and southern Plains area was very beneficial.

It was too cool for gardens and truck crops in the Central States, but truck as a rule made fairly good progress in the South. Good rains broke the drought in the trucking districts of southeastern Florida early in the month and melons made fair progress in that State. Early peaches showed serious damage in parts of the upper Ohio Valley and eastern West Virginia from the freeze the latter part of March, but the weather during April was generally favorable for all fruits that had escaped the previous freezes, although there was some damage by frost in parts of the more western States, particularly in Utah and Oregon. Oranges and lemons blossomed heavily and were setting well in California, but conditions were rather less favorable in Florida where fruit was dropping in the drier areas.

CLIMATOLOGICAL TABLES.[1]

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, April, 1923.

Section.	Temperature.							Precipitation.					
			Monthly extremes.							Greatest monthly.		Least monthly.	
	Section average.	Departure from the normal.	Station.	Highest.	Date.	Station.	Lowest.	Date.	Section average.	Departure from the normal.	Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	63.3	+0.2	2 stations	90	[2]25	2 stations	24	1	5.97	+1.45	Cochrane	10.91	Eufaula	2.56
Alaska														
Arizona	57.5	−1.0	Gila Bend	99	28	Fort Valley	11	23	0.42	−0.10	Williams	2.49	7 stations	0.00
Arkansas	61.4	+0.2	Calico Rock	95	24	Bee Branch	23	1	6.30	+1.52	Arkansas City	10.24	Harrison	1.87
California	54.3	−2.4	Greenland Ranch	102	16	2 stations	18	[2]3	4.06	+2.38	Giant Forest	17.25	Indio	0.00
Colorado	41.5	−0.7	2 stations	87	[2]17	Estes Park	−10	[2]16	1.31	−0.58	Savage Basin	4.34	Yampa	T.
Florida	71.6	+1.8	Orlando	99	23	3 stations	34	1	2.39	−0.37	De Funiak Springs	8.92	Bradentown	0.01
Georgia	63.7	+0.3	Statesboro	96	23	Clayton	16	1	3.92	+0.36	Canton	7.91	Waycross	0.82
Hawaii	70.5	+0.5	2 stations	90	[2]25	Volcano Observatory, Hawaii.	49	16	11.70	+3.71	Glenwood, Hawaii	60.80	Kekaha, Kauai	2.22
Idaho	44.2	−0.5	Hollister	88	17	Stanley	0	[2]8	1.86	+0.38	Cuprum	4.02	Glenns Ferry	0.10
Illinois	51.2	−0.6	Harrisburg	89	22	3 stations	16	1	2.39	−1.02	New Burnside	5.12	Freeport	0.85
Indiana	49.0	−2.7	Madison	87	27	Laporte	7	1	2.47	−1.00	Rome	5.12	Notre Dame	0.90
Iowa	48.4	−0.3	3 stations	85	[2]29	Inwood	11	8	2.09	−0.77	Little Sioux	4.26	Keosauqua	0.47
Kansas	54.3	+0.7	3 stations	88	[2]19	Smith Center	12	8	2.49	−0.15	Overbrook	5.06	Hugoton	0.15
Kentucky	54.8	−1.1	2 stations	90	[2]22	2 stations	13	1	4.88	+0.94	Taylorsville	6.79	Jackson	2.96
Louisiana	67.9	+1.0	Alexandria	92	24	2 stations	32	[2]1	6.24	+1.52	Alexandria	12.97	Morgan City	1.60
Maryland-Delaware	51.5	−0.8	Frederick, Md	88	21	Grantsville, Md	−3	1	4.16	+0.82	Crisfield, Md	7.09	State Sanatorium, Md.	2.29
Michigan	39.6	−2.6	2 stations	83	[2]20	Bergland	−34	1	1.89	−0.45	Mackinac Island	4.30	Sidnaw	0.40
Minnesota	40.7	−2.2	Red Lake	88	19	Warroad	−10	3	1.72	−0.29	Canby	4.04	Red Lake	0.21
Mississippi	64.1	+0.1	Waynesboro	90	26	Hernando	23	1	8.54	+3.12	Brookhaven	16.16	Poplarville	3.26
Missouri	54.2	−0.6	Hollister	92	23	Lebanon	14	1	3.12	−0.74	Poplar Bluff	6.08	Gorin	1.12
Montana	41.6	−0.6	Livingston	87	16	Wheaton	−12	7	1.08	+0.01	Livingston	5.84	Medicine Lake	0.22
Nebraska	48.1	−0.7	3 stations	91	19	Harrison	6	24	2.50	+0.02	Table Rock	6.27	Bingham	0.25
Nevada	47.6	−1.3	2 stations	89	[2]16	Rye Patch	4	24	1.12	+0.42	Lamoille	3.31	2 stations	0.10
New England	42.4	−0.2	2 stations	87	21	Bloomfield, Vt	−12	1	5.03	+1.97	Cornish, Me	7.59	Cornwall, Vt	2.35
New Jersey	50.0	+0.5	Paterson	91	21	Culvers Lake	3	1	3.59	−0.10	Camp Dix	6.59	Phillipsburg	2.27
New Mexico	50.5	+0.1	Deming (near)	91	29	McGaffey Ranger Station.	8	5	1.25	+0.13	Logan	4.30	3 stations	0.00
New York	43.3	−1.0	Rhinebeck	92	21	North Lake	−24	1	2.59	−0.21	Medford	5.01	Lauterbrunnen	0.40
North Carolina	57.1	−0.5	4 stations	91	[2]21	3 stations	7	1	4.18	+0.61	Rock House	6.90	Wilmington	1.28
North Dakota	38.6	−3.1	Jamestown	89	18	Willow City	−15	1	1.45	+0.07	Dunn Center	3.82	Pembina	T.
Ohio	48.4	−1.4	Clarington	88	22	2 stations	2	1	2.60	−0.58	Peebles	5.76	Youngstown	1.16
Oklahoma	60.2	+0.5	Holdenville	93	7	Oakwood	22	5	4.00	+0.84	McAlester	7.43	Kenton	0.60
Oregon	48.3	+0.7	2 stations	88	16	Crater Lake	5	18	2.33	−0.08	Willow Creek	7.27	Warmspring	0.15
Pennsylvania	48.3	−0.4	Catawissa	89	21	3 stations	−5	1	2.94	−0.57	Coatesville	5.89	Turnerville	1.00
Porto Rico	74.1	−1.1	2 stations	94	[2]19	Aibonito	47	[2]15	5.87	+1.12	Maricao	14.55	Santa Isabel	1.77
South Carolina	61.5	−0.9	7 stations	94	23	Landrum	18	1	3.48	+0.50	Anderson	6.25	Paris Island	0.70
South Dakota	44.4	−0.9	2 stations	95	[2]18	Mud Butte	−5	8	1.72	−0.17	Castlewood	4.08	Elk Mountain	0.31
Tennessee	57.6	−0.9	2 stations	88	[2]23	2 stations	14	1	5.07	+0.55	Waynesboro	9.42	Elizabethtown	2.19
Texas	66.2	+0.1	San Benito	103	20	Lieb	27	8	4.16	+0.94	Bon Wier	13.88	3 stations	0.00
Utah	45.4	−1.8	St. George	83	16	Laketown	9	8	2.07	+0.80	High Line City Creek	6.04	Kelton	0.06
Virginia	53.8	−0.6	Columbia	87	21	Burkes Garden	3	1	3.51	+0.20	Diamond Springs	6.85	Radford	1.64
Washington	49.5	+1.8	Hanford	88	16	Bumping Lake	20	9	1.61	−0.54	Quinialt	6.83	Wapato	0.05
West Virginia	50.1	−1.2	Sutton	88	[2]21	Cheat Bridge	−4	1	3.45	−0.10	Bruceton Mills	6.08	Upper Tract	1.00
Wisconsin	41.0	−2.3	Wisconsin Rapids	85	26	Long Lake	−18	1	2.17	−0.27	Stevens Point	5.35	Cecil	0.66
Wyoming	38.6	−1.9	Deaver	90	18	Moran	−4	10	1.70	+0.09	Middle Fork Ranger Station.	5.58	Hyattville	0.00

[1] For description of tables and charts, see REVIEW, July, 1922, pp. 384-385.

[2] Other dates also.

CORRECTIONS.

REVIEW, 1922 and 1923: In Table I the heights of the thermometer and anemometer at Hatteras, N. C., should be 11 feet and 50 feet, respectively, as follows: March, 1922, page 165; June, 1922, page 333; and likewise in each issue subsequent to June to and including March, 1923.

TABLE I.—*Climatological data for Weather Bureau stations, April, 1923.*

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation.			Wind.					Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet and ice on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. ÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with 0.01, or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F.	°F.		°F.	°F.		°F.	°F.		°F.	°F.	%	*In.*	*In.*		*Miles.*								0–10	*In.*	*In.*
New England.							43.6	−0.1											71	4.45	+1.4										5.5		
Eastport	76	67	85	29.82	29.91	−.02	36.4	−2.6	62	21	43	6	1	29	28		34	30	78	4.17	+1.2	14	9,547	sw.	58	se.	30	7	7	16	6.9	7.9	0.0
Greenville, Me	1,070	6	....	28.72	29.91	.....	34.9	.....	66	21	44	−1	1	26	33		....	....	....	5.97	.....	16	.....	.....	.....	.....	.....	9	4	17	....	5.4	0.0
Portland, Me	103	82	117	29.82	29.94	−.02	42.0	−1.0	82	21	51	9	1	33	36		37	30	68	4.98	+1.9	16	8,170	s.	50	se.	29	10	11	9	5.3	3.1	0.0
Concord	288	70	79	29.61	29.92	−.07	44.0	+0.6	83	21	55	8	1	33	47		....	....	....	4.82	+2.0	11	4,939	w.	25	n.	24	12	7	11	5.2	0.7	0.0
Burlington	404	11	48	29.48	29.93	−.06	40.2	−0.5	78	21	50	5	1	31	38		....	....	....	3.13	+1.3	14	8,614	n.	52	s.	8	7	11	12	6.2	0.6	0.0
Northfield	876	12	60	28.97	29.94	−.05	39.4	−0.8	81	21	50	1	1	28	50		36	31	72	3.60	+1.5	13	6,876	s.	31	ne.	25	7	10	13	6.4	1.1	0.0
Boston	125	115	188	29.80	29.94	−.03	48.2	+1.8	87	21	58	13	1	38	39		41	34	61	5.26	+1.7	12	9,077	w.	41	s.	29	9	12	9	5.4	T.	0.0
Nantucket	12	14	90	29.94	29.95	−.02	43.0	−1.2	68	21	49	15	1	37	21		39	36	82	4.27	+1.6	13	14,174	sw.	49	s.	29	11	9	10	5.1	0.0	0.0
Block Island	26	11	46	29.92	29.94	−.04	43.8	−0.2	70	21	50	14	1	37	23		40	37	83	5.78	+2.2	13	14,440	sw.	48	nw.	1	13	6	11	5.0	0.0	0.0
Providence	160	215	251	29.77	29.95	−.03	47.1	+0.5	86	21	57	11	1	37	38		41	34	66	4.75	+1.0	13	10,995	nw.	53	nw.	24	9	10	11	5.4	0.0	0.0
Hartford	159	122	140	29.77	29.95	−.04	47.9	+1.2	87	21	58	11	1	37	38		41	34	62	4.19	+0.6	11	7,348	s.	38	sw.	8	8	11	11	5.8	0.2	0.0
New Haven	106	74	153	29.85	29.96	−.03	47.8	+0.6	85	21	57	13	1	39	41		41	34	63	4.01	+0.4	13	8,089	sw.	37	s.	29	15	6	9	4.3	T.	0.0
Middle Atlantic States.							51.3	+0.1											64	3.18	+0.1										4.8		
Albany	97	102	115	29.85	29.95	−.05	46.1	−0.7	89	21	57	9	1	35	44		40	32	62	2.63	+0.2	9	6,707	s.	34	s.	8	13	11	6	4.3	0.5	0.0
Binghamton	871	10	84	29.02	29.96	−.06	45.9	+1.5	84	21	57	7	1	35	40		....	....	....	2.23	0.0	12	5,269	nw.	34	sw.	8	8	6	16	6.5	0.2	0.0
New York	314	414	454	29.63	29.97	−.03	49.4	0.0	83	21	58	12	1	41	36		42	35	60	2.07	−1.2	9	15,028	nw.	64	nw.	5	10	11	9	5.3	0.0	0.0
Harrisburg	374	94	104	29.59	30.00	−.02	51.3	+0.6	82	21	61	11	1	41	31		43	34	57	1.74	−0.8	7	6,173	w.	35	sw.	3	10	8	12	5.6	2.3	0.0
Philadelphia	114	123	190	29.87	30.00	−.01	52.6	+0.5	84	21	62	14	1	43	34		45	37	61	5.09	+2.2	11	8,822	nw.	36	s.	5	13	7	10	5.2	1.8	0.0
Reading	325	81	98	29.62	29.98	.....	50.9	.....	85	21	61	12	1	41	30		44	37	62	3.24	0.0	10	2,751	nw.	20	sw.	5	14	8	8	4.6	3.3	0.0
Scranton	805	111	119	29.10	29.97	−.05	48.3	+1.2	83	21	59	8	1	38	35		42	36	66	2.92	+0.3	12	6,511	s.	31	sw.	6	9	8	13	5.9	T.	0.0
Atlantic City	52	37	172	29.94	30.00	.00	48.4	+0.6	79	20	56	15	1	41	34		44	39	74	4.57	+1.6	9	15,225	s.	64	ne.	14	16	6	8	4.0	T.	0.0
Cape May	18	13	49	30.01	30.03	+.04	49.2	+0.8	79	20	56	16	1	42	33		44	40	76	3.08	+0.1	10	7,985	s.	50	s.	28	15	5	10	4.5	T.	0.0
Sandy Hook	22	10	55	29.94	29.96	.....	48.2	.....	80	21	56	14	1	40	29		43	38	72	2.33	.....	9	12,355	sw.	65	s.	28	12	9	9	5.0	T.	0.0
Trenton	190	159	183	29.77	29.98	.....	50.2	.....	83	21	61	11	1	40	37		43	35	60	3.34	0.0	11	10,137	sw.	46	w.	22	11	11	8	5.3	1.7	0.0
Baltimore	123	100	113	29.86	30.00	−.01	53.6	0.0	84	20	63	15	1	44	31		46	38	59	3.68	+0.4	9	5,096	s.	31	ne.	14	13	7	10	4.9	0.5	0.0
Washington	112	62	85	29.88	30.00	−.02	53.6	+0.3	85	21	64	15	1	43	36		46	37	57	3.94	+0.7	7	5,866	s.	33	w.	5	14	8	8	4.4	0.5	0.0
Lynchburg	681	153	188	29.26	30.01	−.01	55.8	−1.5	83	23	68	20	1	44	40		48	40	61	2.71	−0.5	8	6,365	sw.	36	nw.	8	16	5	9	4.4	0.0	0.0
Norfolk	91	170	205	29.92	30.03	+.02	57.2	+0.4	82	5	67	23	1	48	32		49	43	67	3.59	−0.2	8	10,555	s.	48	w.	5	17	4	9	4.3	0.0	0.0
Richmond	144	11	52	29.86	30.01	−.01	55.8	−1.4	83	20	67	19	1	44	36		47	40	61	3.96	+0.5	9	7,199	ne.	42	sw.	5	18	4	8	3.5	0.0	0.0
Wytheville	2,304	49	55	27.63	30.01	−.02	51.2	−0.8	77	27	63	14	1	40	38		43	36	61	2.14	−1.5	8	5,020	w.	31	sw.	21	19	4	7	3.6	0.0	0.0
South Atlantic States.							61.8	−0.3											72	2.40	−0.8										5.0		
Asheville	2,255	70	84	27.68	30.03	.00	53.8	−0.1	78	23	65	20	1	43	35		46	39	65	2.57	−0.6	12	6,831	nw.	44	nw.	23	13	11	6	4.7	0.0	0.0
Charlotte	779	55	62	29.18	30.02	−.01	59.0	−0.8	88	23	69	24	1	49	33		51	45	66	4.23	+0.8	12	4,158	s.	25	nw.	23	10	9	11	5.5	0.0	0.0
Hatteras	11	11	50	30.01	30.02	+.01	59.1	−0.7	76	22	66	31	1	52	21		55	51	78	2.58	−1.8	11	9,165	n.	42	s.	29	13	9	8	4.3	0.0	0.0
Manteo	12	5	42	....	....	.....	57.2	.....	84	22	...	28	1	...	30		....	....	....	4.65	.....	4	.....	ne.	....	....	....	17	3	10	....	0.0	0.0
Raleigh	376	103	110	29.62	30.02	−.01	58.4	−0.6	85	23	69	23	1	48	36		51	45	66	5.32	+1.8	9	6,377	sw.	44	w.	5	12	9	9	4.6	0.0	0.0
Wilmington	78	81	91	29.96	30.04	+.01	61.2	−0.8	88	23	71	29	1	52	30		56	52	76	1.28	−1.6	9	6,335	sw.	32	sw.	5	10	13	7	4.8	0.0	0.0
Charleston	48	11	92	29.98	30.03	.00	64.4	−0.1	93	23	72	37	1	57	29		58	55	75	1.06	−1.9	5	8,092	sw.	35	nw.	13	7	15	8	5.6	0.0	0.0
Columbia, S. C	351	41	57	29.66	30.04	+.01	62.2	−0.6	90	23	73	29	1	51	31		54	50	73	2.17	−0.7	11	5,160	ne.	33	n.	23	10	10	10	5.0	0.0	0.0
Due West	711	10	55	29.28	30.06	.....	60.0	.....	89	23	71	28	1	49	32		....	....	....	4.95	.....	12	6,069	sw.	42	w.	13	10	7	13	5.3	0.0	0.0
Greenville, S. C	1,039	113	122	28.91	30.01	.....	58.6	.....	88	23	69	26	1	48	31		51	46	68	5.77	.....	14	6,140	sw.	46	n.	23	12	10	8	4.8	0.0	0.0
Augusta	180	62	77	29.82	30.01	−.02	63.7	−0.5	89	23	75	33	1	53	32		56	51	68	2.78	−0.7	9	2,833	s.	14	s.	13	11	6	13	5.5	0.0	0.0
Savannah	65	150	194	29.96	30.02	−.01	66.5	+0.5	91	23	76	38	1	57	27		59	55	75	1.06	−1.9	5	8,770	s.	39	w.	5	12	12	6	4.6	0.0	0.0
Jacksonville	43	209	245	29.97	30.02	−.02	69.2	+0.5	89	23	77	50	18	62	24		62	60	80	0.98	−1.7	6	9,428	ne.	50	nw.	29	7	17	6	5.3	0.0	0.0
Florida Peninsula.							75.3	+1.6											74	1.30	−0.6										3.6		
Key West	22	10	64	29.97	29.99	−.03	77.9	+2.2	87	14	84	65	19	72	19		70	67	72	1.08	−0.2	3	6,499	se.	50	nw.	17	22	7	1	2.4	0.0	0.0
Miami	25	71	79	29.99	30.02	.....	74.9	+0.7	88	29	82	57	19	68	25		69	66	74	2.15	−0.4	9	5,552	se.	25	nw.	18	8	17	5	5.0	0.0	0.0
Sand Key	23	39	72	29.98	30.01	−.01	76.6	.....	84	28	79	66	19	74	13		71	68	76	0.83	.....	3	7,806	se.	40	nw.	17	22	8	0	2.4	0.0	0.0
Tampa	35	79	87	29.98	30.01	−.05	73.0	+2.0	88	23	82	52	19	65	24		65	62	74	0.67	−1.2	7	4,959	w.	30	ne.	2	9	20	1	4.7	0.0	0.0
East Gulf States.							64.8	+0.2											73	5.95	+1.9										5.4		
Atlanta	1,174	190	216	28.78	30.02	−.01	60.2	−0.8	83	23	70	31	1	50	31		53	48	69	3.82	+0.2	12	8,617	nw.	42	w.	13	11	9	10	5.3	0.0	0.0
Macon	370	78	87	29.62	30.02	−.01	63.8	+0.7	86	22	74	36	1	53	33		56	50	64	3.77	+0.4	9	4,726	s.	31	sw.	13	8	6	16	6.1	0.0	0.0
Thomasville	273	49	58	29.72	30.02	−.01	67.7	+1.0	88	24	78	41	1	58	29		60	57	78	3.88	+0.2	8	3,565	sw.	25	sw.	8	5	12	13	6.1	0.0	0.0
Pensacola	56	149	185	29.95	30.01	−.01	66.4	−0.3	82	26	72	38	1	60	22		63	61	85	6.56	+3.4	9	9,602	s.	74	sw.	4	11	5	14	5.8	0.0	0.0
Apalachicola	36	42	49	29.97	30.01	.....	67.2	.....	83	29	74	44	1	61	20		62	60	82	0.51	.....	3	6,077	sw.	31	n.	9	9	18	3	4.2	0.0	0.0
Anniston	741	9	57	29.24	30.04	+.01	60.4	+0.1	84	22	72	26	1	49	38		....	....	....	6.65	+3.0	14	4,468	n.	30	w.	13	12	10	8	4.9	0.0	0.0
Birmingham	700	11	48	29.27	30.03	+.01	62.2	−1.3	85	22	73	28	1	52	31		54	47	65	7.58	+3.9	12	5,325	s.	40	se.	12	13	7	10	4.7	0.0	0.0
Mobile	57	125	161	29.94	30.00	−.02	67.8	+1.6	87	26	76	38	1	59	27		61	58	79	4.39	0.0	10	7,222	s.	51	se.	4	8	13	9	5.4	0.0	0.0
Montgomery	223	100	112	29.78	30.03	.00	65.2	−0.1	87	22	75	32	1	55	29		57	51	66	5.32	+1.1	11	4,898	sw.	24	nw.	29	9	11	10	5.5	0.0	0.0
Corinth	469	6	....	....	....	.....	61.2	.....	83	22	72	27	1	50	34		....	....	....	7.04	.....	11	.....	se.	....	....	....	7	20	3	....	0.0	0.0
Meridian	375	85	93	29.61	30.00	−.02	63.8	−0.3	86	22	74	31	1	54	34		57	52	71	8.80	+3.8	14	4,340	n.	30	se.	20	10	9	11	5.3	0.0	0.0
Vicksburg	247	65	73	29.72	30.01	+.01	66.0	+0.4	86	22	75	36	1	57	26		58	54	73	10.16	+5.0	12	4,934	se.	36	nw.	4	9	12	9	5.6	0.0	0.0
New Orleans	53	76	84	29.94	29.99	−.01	69.7	+0.9	86	26	78	42	1	62	25		63	59	74	4.48	−0.4	9	5,223	s.	24	s.	12	10	11	9	5.3	0.0	0.0
West Gulf States.							66.2	+0.4											76	4.38	+0.9										5.7		
Shreveport	249	77	93	29.70	29.97	.00	66.0	+0.2	86	22	75	37	1	57	28		58	52	67	4.40	−0.2	17	5,586	se.	32	ne.	12	14	9	7	4.5	0.0	0.0
Bentonville	1,303	11	44	....	....	.....	57.3	+0.4	85	23	68	30	8	46	36		....	....	....	2.47	.....	12	.....	.....	.....	.....	.....	10	6	14	....	0.0	0.0
Fort Smith	457	79	94	29.46	29.94	−.02	61.8	+0.1	86	23	72	33	1	51	34		54	49	70	4.12	+0.2	11	6,503	e.	39	sw.	20	10	6	14	5.9	0.0	0.0
Little Rock	357	136	144	29.58	29.96	−.02	62.4	+0.3	84	28	72	32	1	52	27		54	48	66	7.69	+3.2	11	6,520	s.	43	s.	28	11	11	8	5.1	0.0	0.0
Brownsville	57	53	61	29.82	29.88	.....	75.7	.....	95	28	83	57	1	69	26		70	68	87	0.35	.....	3	7,044	s.	30	se.	19	5	17	8	5.4	0.0	0.0
Corpus Christi	20	11	73	29.89	29.91	−.04	72.2	+1.3	87	28	77	57	1	67	25		68	66	84	0.61	−1.2	4	10,026	se.	47	ne.	12	5	9	16	6.9	0.0	0.0
Dallas	512	109	117	29.40	29.94	.....	66.0	.....	90	7	76	40	1	56	31		....	....	....	6.39	.....	12	6,997	se.	35	sw.	20	9	12	9	5.7	0.0	0.0
Fort Worth	670	106	114	29.21	29.91	−.03	66.0	+0.7	91	7	76	40	1	56	30		57	52	68	5.30	+2.6	11	7,335	se.	39	w.	20	8	12	10	5.7	0.0	0.0
Galveston	54	106	114	29.90	29.96	−.01	69.4	+0.7	84	29	74	50	1	65	16		65	64	87	4.45	+1.3	9	8,878	se.	39	se.	11	9	8	13	6.0	0.0	0.0
Groesbeck	461	11	56	29.46	29.94	.....	66.2	.....	86	28	75	43	1	57	28		....	....	....	5.41	.....	10	8,218	se.	53	ne.	11	8	7	15	5.9	0.0	0.0
Houston	138	111	121	29.80	29.95	.....	69.8	+0.2	86	25	77	45	1	62	24		....	....	....	9.66	.....	12	6,772	se.	33	ne.	12	10	10	10	5.2	0.0	0.0
Palestine	510	64	72	29.42	29.95	−.01	66.6	+0.6	88	28	76	40	1	57	31	60	56	74		4.75	+0.7	9	6,182	s.	30	se.	11	6	11	13	5.9	0.0	0.0
Port Arthur	34	58	66	29.91	29.95	.....	69.6	.....	84	29	75	46	1	64	20	64	62	81		4.42	.....	9	7,763	se.	38	nw.	12	10	4	16	5.9	0.0	0.0
San Antonio	701	119	132	29.19	29.91	−.02	69.2	+0.2	91	28	78	47	1	60	31	62	58	74		3.24	+0.3	11	6,004	se.	34	nw.	12	9	8	13	5.9	0.0	0.0
Taylor	582	55	63	29.34	29.95	.00	67.4	−0.1	87	28	76	45	1	58	33		....	....	....	4.91	+0.9	10	6,549	se.	30	sw.	20	7	10	13	6.2	0.0	0.0

TABLE I.—*Climatological data for Weather Bureau stations, April, 1923*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.									Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation.			Wind.				Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet and ice on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. ÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.				Total.	Departure from normal.	Days with 0.01, or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.					
Ohio Valley and Tennessee.	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	*In.*	*In.*		*Miles.*							*0–10*	*In.*	*In.*
							53.7	−1.0										63	3.97	+0.4									5.4		
Chattanooga	762	189	213	29.21	30.02	−.01	59.4	−0.9	85	23	70	26	1	49	31	50	42	59	5.56	+1.2	13	6,388	sw.	46	sw.	27	12	10	8	4.9	0.0	0.0
Knoxville	996	102	111	28.96	30.02	−.01	57.4	−0.6	83	23	69	23	1	46	35	49	42	61	5.65	+1.0	13	5,111	sw.	42	sw.	28	9	9	12	5.8	0.0	0.0
Memphis	399	76	97	29.56	29.99	−.01	61.5	−0.3	82	22	70	30	1	53	27	53	46	62	6.55	+1.7	14	6,697	s.	54	sw.	4	10	10	10	5.6	0.0	0.0
Nashville	546	168	191	29.44	30.03	+.02	58.3	−0.7	84	22	69	25	1	48	32	50	43	64	4.26	−0.1	11	7,438	s.	37	sw.	21	12	6	12	5.2	0.0	0.0
Lexington	989	193	230	28.95	30.02	.00	53.3	−0.4	80	27	63	20	1	43	34	.....	.....	.....	5.43	+2.1	12	10,103	sw.	54	s.	21	11	9	10	4.9	0.0	0.0
Louisville	525	219	255	29.43	30.02	+.01	54.6	−1.8	85	27	65	22	1	45	30	46	37	58	4.53	+0.5	11	8,940	s.	48	sw.	21	12	9	9	5.2	0.0	0.0
Evansville	431	139	175	29.54	30.01	+.01	55.9	−0.5	82	27	66	24	1	46	29	48	41	62	4.54	+1.1	9	8,525	sw.	47	sw.	21	10	13	7	5.3	0.0	0.0
Indianapolis	822	194	230	29.10	30.00	.00	49.9	−2.2	78	27	60	20	1	40	34	43	36	62	1.94	−1.5	10	9,942	sw.	52	w.	7	11	8	11	5.5	T.	0.0
Royal Center	736	11	55	29.18	29.99	.....	47.0	.....	77	20	58	19	1	36	38	.....	.....	.....	1.75	.....	7	9,329	sw.	41	w.	7	8	8	14	6.0	0.9	0.0
Terre Haute	575	96	129	29.37	29.99	.....	51.6	.....	81	27	62	23	1	41	38	45	38	66	2.66	.....	10	8,320	s.	40	sw.	21	6	16	8	5.6	1.0	0.0
Cincinnati	628	11	51	29.32	30.00	−.01	51.7	−0.7	81	27	63	18	1	40	31	.....	38	65	2.96	0.0	12	6,845	sw.	38	sw.	22	12	8	10	5.0	0.0	0.0
Columbus	824	179	222	29.12	30.00	−.02	49.6	−1.6	77	27	61	15	1	39	35	42	36	65	2.12	−0.8	8	9,458	nw.	50	sw.	8	9	13	8	5.2	T.	0.0
Dayton	899	181	216	29.03	30.00	.....	50.1	−1.6	78	27	61	18	1	39	32	43	37	66	1.56	−1.3	9	9,393	sw.	52	sw.	21	13	10	7	4.6	T.	0.0
Elkins	1,947	59	67	27.94	30.02	−.01	48.0	−0.7	79	21	61	5	1	35	47	41	34	64	3.20	−0.1	11	4,933	w.	31	w.	22	9	9	12	5.9	T.	0.0
Parkersburg	638	77	84	29.36	30.02	−.01	52.6	−0.4	81	27	65	15	1	40	40	44	36	60	3.47	+0.6	8	4,812	se.	30	w.	22	11	9	10	5.4	0.0	0.0
Pittsburgh	842	353	410	29.08	30.00	−.02	49.8	−1.4	80	21	61	11	1	39	37	42	34	62	3.82	+0.9	10	9,586	sw.	47	nw.	18	7	11	12	5.9	3.0	0.0
Lower Lake Region.							44.1	−1.4											2.02	0.3									5.6		
Buffalo	767	247	280	29.12	29.96	−.05	40.4	−2.4	77	21	49	5	1	32	33	35	29	68	1.17	−1.3	15	13,705	sw.	76	sw.	8	7	11	12	6.1	0.2	0.0
Canton	448	10	61	29.41	29.92	.....	39.6	−2.9	79	21	49	1	1	30	32	.....	.....	.....	2.41	+0.2	14	9,646	sw.	62	w.	8	12	8	10	5.3	2.1	0.0
Oswego	335	76	91	.....	29.95	−.06	41.1	−2.5	72	21	49	11	1	33	38	.....	.....	.....	1.59	−0.7	15	8,076	w.	37	w.	8	9	8	13	.....	0.8	0.0
Rochester	523	86	102	29.39	29.97	−.04	43.7	−1.2	80	21	53	7	1	35	35	37	30	62	1.55	−0.9	16	7,537	w.	50	w.	8	11	5	14	6.1	1.4	0.0
Syracuse	597	97	113	29.32	29.97	−.04	43.8	−0.6	81	21	53	7	1	34	33	.....	.....	.....	2.31	0.0	14	8,737	w.	43	w.	8	5	12	13	6.3	2.0	0.0
Erie	714	130	166	29.19	29.97	−.05	44.6	−0.5	80	21	53	7	1	36	37	39	33	67	2.23	−0.2	13	10,729	w.	48	se.	15	12	10	8	4.9	2.2	0.0
Cleveland	762	190	201	29.15	29.99	−.03	45.8	−0.4	78	20	54	11	1	37	40	38	32	65	2.21	−0.1	9	10,553	w.	52	w.	8	10	9	11	5.4	0.1	0.0
Sandusky	629	62	70	29.30	29.99	−.03	46.9	−0.3	79	20	56	14	1	38	39	.....	.....	.....	1.86	−0.7	9	7,491	sw.	36	w.	8	8	10	12	5.7	0.1	0.0
Toledo	628	208	243	29.30	29.98	−.03	46.8	−0.8	78	20	57	15	1	37	39	40	34	64	2.77	+0.5	10	13,072	sw.	58	w.	8	12	9	9	4.8	1.6	0.0
Fort Wayne	856	113	124	29.06	29.99	.....	47.4	−1.9	78	20	58	18	1	37	36	40	32	60	1.42	.....	10	8,695	sw.	44	sw.	21	8	9	13	5.9	T.	0.0
Detroit	730	218	258	29.17	29.98	−.04	45.2	−1.0	77	20	55	14	1	35	38	40	35	71	2.11	−0.2	9	9,810	sw.	50	w.	8	10	5	15	5.8	6.0	0.0
Upper Lake Region.							39.5	−1.5										71	1.75	−0.6									5.1		
Alpena	609	13	92	29.28	29.96	−.06	36.7	−1.9	80	20	46	−2	1	28	38	33	28	73	2.64	+0.4	9	8,852	nw.	40	nw.	8	11	10	9	4.9	9.5	0.0
Escanaba	612	54	60	29.30	29.98	−.04	34.0	−3.2	62	30	43	−1	1	25	32	30	26	74	2.44	+0.4	9	6,679	n.	35	n.	7	16	9	5	3.9	21.2	0.0
Grand Haven	632	54	89	29.27	29.96	−.05	41.2	−2.5	72	20	49	11	1	33	27	37	32	73	2.00	−0.4	11	10,087	s.	40	s.	11	9	10	11	5.6	2.9	0.0
Grand Rapids	707	70	87	29.19	29.97	−.05	45.0	−1.2	80	20	55	14	1	35	32	38	31	62	2.19	−0.3	11	5,155	w.	27	w.	8	7	12	11	6.0	3.7	0.0
Houghton	684	62	99	29.23	29.97	−.05	35.4	−1.5	79	20	45	−10	1	26	42	.....	.....	.....	0.89	−1.1	11	6,732	e.	33	w.	10	11	9	10	5.0	4.7	0.0
Lansing	878	11	62	29.00	29.96	.....	44.0	−1.6	80	20	56	8	1	32	39	37	31	67	1.56	−1.0	11	5,940	nw.	25	w.	8	10	9	11	5.3	3.1	0.0
Ludington	637	60	66	29.25	29.96	.....	39.6	.....	69	20	48	10	1	32	28	35	31	73	2.66	.....	11	7,803	s.	32	s.	2	12	11	7	4.6	6.1	0.0
Marquette	734	77	111	29.18	30.00	−.02	36.6	−0.9	77	20	44	5	1	29	39	32	27	70	1.43	−0.6	7	6,117	nw.	31	sw.	12	9	10	11	5.5	13.6	0.0
Port Huron	638	70	120	29.25	29.96	−.06	42.2	−0.8	79	20	52	9	1	33	45	37	31	70	1.70	−0.4	11	9,714	sw.	48	w.	8	10	9	11	5.2	2.6	0.0
Saginaw	641	69	77	29.26	29.96	.....	43.4	.....	79	20	54	8	1	33	39	38	34	75	1.31	−1.4	10	7,679	nw.	35	se.	21	9	8	13	5.7	1.4	0.0
Sault Sainte Marie	614	11	52	29.27	29.99	−.04	30.2	−5.5	64	20	42	−13	1	19	42	28	25	78	1.66	−0.4	11	5,196	nw.	39	nw.	11	13	9	8	4.5	15.2	T.
Chicago	823	140	310	29.08	29.98	−.02	46.6	−1.1	79	20	55	20	1	38	35	40	33	63	1.38	−1.5	8	9,398	ne.	48	s.	21	12	10	8	4.9	0.6	0.0
Green Bay	617	109	144	29.28	29.95	−.06	40.4	−0.3	78	19	49	15	1	32	35	35	30	71	2.33	−0.1	9	8,614	s.	34	n.	7	12	9	9	5.4	12.5	0.0
Milwaukee	681	125	139	29.22	29.96	−.03	44.2	+0.4	78	19	52	19	1	36	30	37	32	69	1.90	−0.8	12	7,645	w.	36	sw.	21	11	8	11	5.2	6.8	0.0
Duluth	1,133	11	47	28.73	29.98	−.03	37.5	+0.5	79	19	45	11	8	29	31	32	27	72	1.11	−1.0	10	9,508	ne.	39	ne.	13	10	12	8	5.0	2.2	0.0
North Dakota.							39.7	−1.0										69	1.69	−0.2									5.9		
Moorhead	940	50	58	28.92	29.96	−.03	40.2	−0.4	82	19	49	18	6	31	37	35	30	70	1.28	−1.0	10	6,153	n.	24	nw.	20	9	9	12	5.9	3.3	0.0
Bismarck	1,674	8	57	28.17	29.98	+.01	41.1	−1.0	81	18	53	16	2	30	40	35	28	66	2.01	+0.1	8	6,064	nw.	32	sw.	30	9	11	10	5.6	9.1	0.0
Devils Lake	1,482	11	44	28.36	29.96	−.03	37.4	−0.8	77	19	47	9	2	28	36	33	28	74	1.44	−0.6	9	7,102	n.	26	ne.	23	9	8	13	5.5	5.4	0.0
Ellendale	1,457	10	56	28.38	29.97	.....	40.4	.....	86	19	51	12	8	29	44	.....	.....	.....	1.38	.....	7	10,188	ne.	45	n.	14	9	9	12	6.0	4.5	0.0
Grand Forks	835	12	89	.....	.....	.....	38.4	.....	80	19	48	14	15	28	38	34	.....	.....	1.36	.....	10	.....	n.	.....	.....	.....	14	4	12	.....	9.1	0.0
Williston	1,878	41	48	27.93	29.94	−.02	40.2	−1.8	83	18	51	13	6	30	43	34	27	66	2.03	+0.8	9	5,411	ne.	29	nw.	19	6	8	16	6.7	14.9	0.0
Upper Mississippi Valley.							49.5	−1.0										65	2.10	−0.8									5.4		
Minneapolis	918	102	208	28.94	29.93	.....	44.0	.....	83	19	53	16	8	35	35	.....	.....	.....	1.99	−0.4	9	8,652	se.	41	s.	20	11	6	13	5.6	11.0	0.0
St. Paul	837	236	261	29.04	29.96	−.03	43.7	−1.9	81	19	53	15	8	34	35	.....	.....	.....	2.20	−0.1	9	8,909	se.	50	s.	20	15	7	8	4.9	11.0	0.0
La Crosse	714	11	48	29.18	29.96	−.02	45.4	−1.8	81	19	56	20	1	35	37	.....	.....	.....	1.69	−0.6	10	3,972	s.	25	s.	19	12	4	14	5.6	2.0	0.0
Madison	974	70	78	28.91	29.98	−.01	44.0	−1.4	77	19	53	17	1	35	32	38	33	72	2.59	+0.2	9	6,846	nw.	31	sw.	19	8	8	14	6.1	6.4	0.0
Wausau	1,247	4	.....	28.62	29.98	.....	39.5	.....	77	19	50	10	9	29	36	.....	.....	.....	1.46	.....	8	.....	se.	.....	.....	.....	15	3	12	4.8	15.4	0.0
Charles City	1,015	10	49	28.87	29.96	−.02	45.4	−0.9	81	30	56	22	8	35	38	40	35	71	2.60	−0.2	10	5,357	se.	28	s.	19	14	6	10	4.6	4.0	0.0
Davenport	606	71	79	29.30	29.96	−.02	49.6	−0.3	82	30	60	26	8	39	36	42	35	62	0.59	−2.3	11	6,355	sw.	29	sw.	2	12	8	10	5.3	1.0	0.0
Des Moines	861	84	97	29.02	29.94	−.03	50.2	+0.1	80	30	61	24	8	40	36	44	39	70	1.76	−1.2	8	6,188	sw.	42	sw.	19	13	5	12	5.2	T.	0.0
Dubuque	698	81	96	29.22	29.98	.00	47.0	−1.6	80	19	57	20	1	37	35	40	33	63	1.48	−1.4	9	4,926	s.	24	nw.	7	8	10	12	6.1	1.0	0.0
Keokuk	614	64	78	29.29	29.97	−.01	51.4	−0.9	82	30	62	25	8	41	41	44	35	57	1.16	−2.2	8	6,656	n.	40	sw.	21	8	6	16	6.1	T.	0.0
Cairo	358	87	93	29.60	29.99	.00	57.8	−0.3	83	22	67	28	1	49	30	49	42	61	4.02	+0.4	13	6,797	s.	38	sw.	21	9	9	12	5.7	0.0	0.0
Peoria	609	11	45	29.31	29.98	−.01	49.4	−1.5	80	30	61	26	1	38	38	43	38	69	1.95	−1.3	12	6,072	s.	29	sw.	21	12	9	9	4.9	1.6	0.0
Springfield, Ill	644	10	91	29.28	29.96	−.02	51.8	−0.9	82	30	63	27	1	41	39	44	37	64	1.72	−1.6	9	7,194	s.	32	s.	7	9	7	14	5.9	T.	0.0
Hannibal	534	74	109	29.39	29.96	−.02	52.6	−0.8	80	30	63	29	8	42	39	.....	.....	.....	2.38	−0.9	10	7,703	sw.	38	sw.	21	8	11	11	5.5	5.0	0.0
St. Louis	567	265	303	29.36	29.97	−.01	55.0	−0.8	83	30	65	26	1	45	44	47	40	63	3.20	−0.3	11	10,231	s.	50	s.	7	7	19	4	5.1	T.	0.0
Missouri Valley.							50.8	+0.2										64	2.44	−0.4									5.0		
Columbia, Mo.	781	11	84	29.12	29.96	−.02	53.3	−1.0	79	30	64	27	8	42	40	.....	.....	.....	4.21	+0.5	11	7,143	s.	35	sw.	21	10	7	13	5.4	1.7	0.0
Kansas City	963	161	181	28.92	29.96	.00	54.1	−0.2	79	30	64	26	8	45	34	46	38	60	1.84	−1.4	13	8,851	s.	39	w.	21	13	9	8	4.9	T.	0.0
St. Joseph	967	11	49	28.90	29.94	.....	53.8	.....	82	30	65	24	8	43	34	45	38	62	2.21	.....	10	7,467	nw.	38	nw.	21	13	11	6	4.8	T.	0.0
Springfield, Mo.	1,324	98	104	28.56	29.97	.00	55.2	−0.5	83	23	65	27	8	45	38	48	41	65	3.33	−0.5	11	7,996	s.	40	sw.	7	15	5	10	4.4	0.0	0.0
Iola	984	11	50	28.90	29.94	−.01	56.5	+2.3	84	23	68	27	8	45	39	.....	.....	.....	2.66	−0.1	11	6,443	s.	30	s.	2	12	7	11	5.1	0.0	0.0
Topeka	987	92	107	.....	.....	.....	54.2	+0.5	82	30	65	24	8	43	34	.....	.....	.....	2.20	−0.5	9	8,732	nw.	40	sw.	2	11	7	12	5.2	T.	0.0
Drexel	1,299	10	54	28.53	29.94	.....	49.3	.....	81	19	61	18	8	38	39	.....	.....	.....	3.25	.....	10	9,618	nw.	48	s.	19	12	7	11	5.1	T.	0.0
Lincoln	1,189	11	84	28.66	29.94	.00	51.2	+0.5	83	30	63	22	8	40	38	43	36	62	2.21	−0.6	8	9,095	s.	46	nw.	21	8	10	12	5.7	T.	0.0
Omaha	1,105	115	122	28.75	29.94	−.01	51.2	0.0	82	19	62	22	8	40	38	44	38	65	1.57	−1.4	8	6,351	nw.	34	nw.	14	14	6	10	4.9	T.	0.0
Valentine	2,598	47	54	27.20	29.94	.00	45.3	−0.4	87	19	58	13	8	32	47	37	29	62	1.34	−1.0	8	7,203	nw.	58	nw.	30	13	10	7	4.9	0.7	0.0
Sioux City	1,135	94	164	28.72	29.94	−.01	48.4	+0.6	84	19	59	20	8	37	37	41	35	66	3.36	+0.6	11	9,498	s.	41	nw.	21	12	10	8	5.2	0.7	0.0
Huron	1,306	59	74	28.55	29.96	.00	44.5	−0.6	88	19	57	11	8	32	42	38	32	70	1.50	−1.2	8	7,699	se.	46	sw.	19	18	4	8	4.3	3.3	0.0
Pierre	1,572	70	75	28.26	29.94	−.01	47.0	+0.2	91	18	59	17	8	35	44	40	33	66	1.54	−0.4	9	6,912	nw.	42	se.	30	13	8	9	4.8	2.5	0.0
Yankton	1,233	49	57	28.62	29.95	.00	48.6	+0.7	87	19	60	20	8	37	37	.....	.....	.....	3.50	+0.7	10	6,974	nw.	40	s.	19	9	11	10	5.7	0.2	0.0

TABLE I.—*Climatological data for Weather Bureau stations, April, 1923*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.											Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation.			Wind.						Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet and ice on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. ÷ 2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.						Total.	Departure from normal.	Days with 0.01, or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.							
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	*°F.*	*°F.*	*°F*		*°F.*	*°F.*		*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	%	*In.*	*In.*		*Miles.*								*0–10*	*In.*	*In.*
Northern Slope.							**42.1**	**−0.9**												**60**	**1.63**	**0.0**										**5.6**		
Billings	3,140	5		27.29	29.94		44.0		85	17	60	9	7	28	57						1.13		8		nw.				8	8	14		0 0	0.0
Havre	2,505	11	44	27.29	29.94	+.01	43.2	−0.5	83	17	55	14	7	31	47	36	27	62			1.24	+0.2	11	5,439	e.	30	sw.	18	11	8	11	5.5	5.7	0.0
Helena	4,110	87	112	25.72	29.94	−.03	42.0	−1.5	75	17	53	7	7	31	39	33	24	54			1.17	0.0	6	6,295	sw.	37	sw.	29	6	8	16	6.4	14.2	0.0
Kalispell	2,973	48	56	26.85	29.92	−.04	42.6	+0.1	78	17	54	19	7	32	42	34	23	52			0.41	−0.6	5	5,065	nw.	31	sw.	17	10	12	8	4.6	1.1	0.0
Miles City	2,371	48	55	27.41	29.98	+.02	44.2	−0.5	83	18	56	15	7	33	35	37	29	63			1.53	+0.4	12	5,212	ne.	30	w.	12	8	8	14	6.2	7.0	0.0
Rapid City	3,259	50	58	26.53	29.98	+.03	42.8	−0.7	84	18	55	8	7	30	45	35	26	55			0.89	−1.4	8	6,279	w.	52	sw.	19	7	15	8	5.6	6.0	0.0
Cheyenne	6,088	84	101	23.89	29.90	−.01	39.6	−1.3	70	18	51	18	23	28	38	32	24	61			3.26	+1.4	9	9,390	w.	56	nw.	7	7	11	12	6.0	14.4	T.
Lander	5,372	60	68	24.54	29.91	−.03	41.2	−1.0	71	17	53	23	26	29	40	34	26	60			2.38	−0.1	5	4,161	sw.	52	sw.	29	12	11	7	5.1	21.0	0.0
Sheridan	3,790	10	47	26.03	29.96	.....	40.2	.....	76	18	53	6	8	27	45	34	26	64			2.47	.....	10	4,648	nw.	39	nw.	12	9	11	10	5.5	16.3	0.0
Yellowstone Park	6,200	11	48	23.77	29.94	−.02	34.8	−2.2	66	17	46	7	7	23	37	29	22	64			1.81	+0.4	15	4,991	s.	30	n.	12	7	7	16	6.3	14.1	T.
North Platte	2,821	11	51	27.01	29.95	+.03	48.1	−0.5	87	19	61	24	8	35	48	40	32	65			2.02	−0.1	10	3,329	n.	22	nw.	20	13	6	11	5.2	3.5	0.0
Middle Slope.							**53.4**	**−0.1**												**59**	**2.06**	**−0.2**										**5.3**		
Denver	5,292	106	113	24.60	29.85	−.05	46.6	−0.5	76	18	58	27	23	35	34	37	24	49			0.60	−1.6	4	6,043	s.	42	nw.	13	10	13	7	5.0	2.0	0.0
Pueblo	4,685	80	86	25.16	29.82	−.06	51.0	+0.5	78	18	65	29	8	37	45	39	27	47			0.54	−0.9	5	5,105	e.	37	nw.	7	7	19	4	5.2	0.7	0.0
Concordia	1,392	50	58	28.44	29.92	−.01	53.7	+0.1	80	30	65	24	8	42	35	45	38	65			3.20	+0.8	10	7,758	s.	35	s.	19	10	11	9	5.4	1.4	0.0
Dodge City	2,509	11	51	27.33	29.93	+.03	54.1	+0.5	83	30	67	25	5	41	43	45	37	62			2.13	+0.3	8	9,380	se.	45	s.	30	11	13	6	4.8	0.0	0.0
Wichita	1,358	139	158	28.48	29.91	−.02	55.8	−0.8	78	30	66	28	8	46	34	48	41	64			1.64	−1.0	9	9,801	s.	52	s.	1	8	13	9	5.4	0.0	0.0
Broken Arrow	765	11	52	29.13	29.95	.....	58.5	.....	84	23	68	33	8	48	37	.....	.....	.....			3.82	.....	11	10,179	se.	43	nw.	27	8	9	13	5.8	0.0	0.0
Muskogee	652	4	.....	.....	.....	.....	61.0	.....	87	23	73	34	8	49	39	.....	.....	.....			5.88	.....	16	.....	nw.	.....	.....	.....	8	16	6	.....	0.0	0.0
Oklahoma City	1,214	10	47	28.65	29.93	+.01	59.3	−0.3	83	7	70	33	5	49	33	51	45	67			4.29	+1.5	9	9,061	s.	36	s.	2	9	11	10	5.6	0.0	0.0
Southern Slope.							**62.4**	**0.0**												**60**	**2.88**	**+1.2**										**5.4**		
Abilene	1,738	10	52	28.10	29.90	.00	63.6	−0.8	88	7	74	39	5	53	34	55	50	69			5.73	+3.4	12	7,988	s.	48	ne.	24	7	8	15	6.4	0.0	0.0
Amarillo	3,676	10	49	26.18	29.88	+.01	56.0	+1.4	82	6	68	35	5	44	39	47	39	65			3.22	+1.5	6	8,500	s.	34	s.	1	12	11	7	4.9	0.0	0.0
Del Rio	944	64	71	28.91	29.87	−.02	70.2	+0.2	92	7	79	50	13	61	34	.....	.....	.....			1.62	−0.3	8	7,584	se.	50	nw.	12	12	4	14	5.6	0.0	0.0
Roswell	3,566	75	85	26.25	29.81	−.04	59.6	−1.0	85	6	72	37	5	47	37	46	31	47			0.96	+0.1	7	7,765	s,	48	nw.	20	12	10	8	4.6	0.0	0.0
Southern Plateau.							**56.6**	**−1.0**												**46**	**0.43**	**+0.1**										**3.5**		
El Paso	3,762	110	133	26.08	29.79	−.04	63.6	−0.2	84	24	76	41	20	51	34	47	27	32			0.04	−0.2	1	9,760	w.	49	sw.	30	17	13	0	3.1	0.0	0.0
Santa Fe	7,013	38	53	23.14	29.82	−.02	45.6	−1.1	67	29	57	27	4	35	29	36	25	51			1.60	+0.7	8	5,606	se.	28	sw.	2	12	9	9	5.0	4.8	0.0
Flagstaff	6,908	10	59	23.24	29.81	−.03	41.6	−0.6	66	15	55	19	23	28	38	33	...	58			1.09	.....	9	7,084	.....	35	sw.	1	13	12	5	.....	5.7	0.0
Phoenix	1,108	11	81	28.70	29.85	−.02	66.6	0.0	92	15	81	40	23	52	43	52	37	41			0.05	−0.4	3	4,483	e.	30	sw.	18	17	8	5	3.6	0.0	0.0
Yuma	141	9	54	29.71	29.86	−.03	68.2	−1.3	95	14	83	44	23	54	40	53	40	43			0.16	+0.1	4	4,598	w.	42	nw.	10	22	5	3	2.5	0.0	0.0
Independence	3,957	9	41	25.89	29.92	+.02	54.0	−2.7	80	16	68	30	7	40	39	43	33	49			0.29	+0.2	3	6,297	nw.	53	sw.	6	15	13	2	3.1	T.	0.0
Middle Plateau.							**46.8**	**−2.0**												**53**	**1.34**	**+0.2**										**5.7**		
Reno	4,532	74	81	25.39	29.93	−.04	46.2	−1.1	74	15	58	26	3	34	40	37	27	54			1.03	+0.4	10	5,715	w.	48	sw.	5	8	13	9	5.3	0.7	0.0
Tonopah	6,090	12	20	23.94	29.84	.....	44.7	.....	67	16	54	22	22	35	27	35	22	46			0.61	−1.1	5	7,279	nw.	42	nw.	6	8	12	10	5.3	3.8	0.0
Winnemucca	4,344	18	56	25.54	29.93	−.03	45.2	−1.5	77	16	59	23	30	32	48	36	26	56			0.79	−0.1	11	6,012	sw.	41	s.	5	10	8	12	5.8	0.7	0.0
Modena	5,479	10	43	24.50	29.84	−.04	44.4	−2.5	71	16	58	21	7	31	43	35	24	54			1.22	+0.4	11	8,515	w.	56	sw.	6	10	13	7	4.7	3.3	0.0
Salt Lake City	4,360	163	203	25.53	29.90	−.02	47.1	−2.5	70	17	56	32	22	39	28	40	32	59			3.56	+1.3	16	6,026	nw.	54	nw.	20	6	7	16	6.8	2.5	0.0
Grand Junction	4,602	60	68	25.26	29.82	−.06	51.0	−2.2	76	17	62	32	4	40	35	40	29	49			0.84	+0.1	9	5,362	se.	38	s.	6	7	11	12	6.3	T.	0.0
Northern Plateau.							**48.9**	**−0.2**												**57**	**1.46**	**+0.1**										**5.9**		
Baker	3,471	48	53	26.37	29.97	−.03	44.1	+0.6	73	16	55	27	13	33	35	38	30	63			1.28	+0.3	9	4,923	se.	27	nw.	22	12	9	9	5.1	T.	0.0
Boise	2,739	78	86	27.09	29.96	−.02	49.4	−1.0	80	16	60	30	13	39	34	41	30	52			1.09	−0.1	12	4,434	se.	34	se.	17	7	12	11	5.8	T.	0.0
Lewiston	757	40	48	29.14	29.96	−.03	52.6	−0.3	85	16	65	34	23	40	40	.....	.....	.....			1.02	−0.1	12	2,772	e.	32	w.	19	5	11	14	6.5	0.0	0.0
Pocatello	4,477	60	68	25.36	29.89	−.05	45.0	−1.8	69	17	55	26	20	35	35	37	29	59			2.57	+0.6	16	6,096	se.	36	sw.	19	6	10	14	6.6	5.0	0.0
Spokane	1,929	101	110	27.89	29.95	−.04	48.1	−0.3	79	16	59	30	6	38	36	40	31	57			1.58	+0.3	10	4,847	sw.	29	sw.	18	7	11	12	6.1	T.	0.0
Walla Walla	991	57	65	28.88	29.95	−.06	54.1	+1.3	84	15	64	38	22	44	38	45	35	52			1.24	−0.5	11	4,355	s.	25	sw.	18	10	12	8	5.3	0.0	0.0
North Pacific Coast Region.							**50.8**	**+1.7**												**78**	**1.96**	**−1.2**										**6.6**		
North Head	211	11	56	29.77	30.00	−.05	48.4	+0.9	66	15	52	39	21	44	19	47	46	91			2.50	−0.7	15	11,980	s.	65	s.	5	0	12	18	7.6	0.0	0.0
Port Angeles	29	8	53	29.98	30.00	.....	47.0	.....	67	15	54	35	13	40	28	.....	.....	.....			0.51	−1.4	7	4,606	sw.	28	sw.	18	10	7	13	5.8	0.0	0.0
Seattle	125	215	250	29.88	30.01	−.02	51.0	+1.6	79	15	58	39	20	44	32	45	39	70			1.67	−0.7	14	6,106	s.	37	s.	18	4	7	19	7.0	0.0	0.0
Tacoma	213	113	120	29.78	30.00	−.03	51.0	+2.1	81	15	59	37	9	43	35	.....	.....	.....			1.14	−1.6	11	4,433	n.	26	sw.	18	4	11	15	6.9	0.0	0.0
Tatoosh Island	86	9	57	29.89	29.99	−.01	47.6	+1.5	61	15	52	36	6	43	13	46	45	93			3.75	−2.6	17	10,464	s.	52	s.	18	1	8	21	7.9	0.0	0.0
Yakima	1,071	5	.....	.....	.....	.....	51.6	.....	81	26	66	27	30	37	48	.....	.....	.....			0.38	.....	5	.....	nw.	.....	.....	.....	8	9	13	5.8	0.0	0.0
Medford	1,425	4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....			.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Portland, Oreg	153	68	106	29.84	29.99	−.07	54.2	+2.4	85	15	64	39	4	45	31	48	42	68			1.90	−1.2	13	4,132	nw.	24	sw.	30	5	8	17	7.1	0.0	0.0
Roseburg	510	9	57	29.47	30.02	−.05	52.8	+1.8	86	15	64	35	9	41	43	46	39	68			2.23	−0.2	15	2,363	n.	29	sw.	2	10	14	6	4.9	0.0	0.0
Middle Pacific Coast Region.							**54.6**	**−0.2**												**73**	**2.95**	**+0.7**										**4.9**		
Eureka	62	73	89	29.99	30.06	−.05	50.5	+1.0	67	25	56	40	30	46	21	47	45	84			2.95	−1.0	15	6,060	n.	30	se.	4	6	9	15	6.6	0.0	0.0
Point Reyes	490	7	18	29.45	29.97	.....	50.6	0.0	73	14	55	43	24	47	28	.....	.....	.....			2.46	.....	10	16,882	nw.	68	nw.	21	9	7	14	5.8	0.0	0.0
Red Bluff	332	50	56	29.61	29.96	−.07	57.4	−1.6	82	15	68	38	2	47	34	49	41	61			3.47	+1.6	12	5,175	se.	28	nw.	20	16	11	3	3.6	0.0	0.0
Sacramento	69	106	117	29.91	29.98	−.03	57.1	−1.0	81	15	67	41	3	48	30	51	45	69			2.87	+0.9	11	5,785	s.	30	se.	4	16	7	7	3.9	0.0	0.0
San Francisco	155	208	243	29.84	30.01	−.04	56.1	+1.1	79	14	62	46	3	50	28	50	46	77			3.92	+2.1	8	6,675	w.	35	w.	20	16	7	7	4.2	0.0	0.0
San Jose	141	12	110	29.86	30.02	.....	56.0	−0.7	82	14	67	37	3	45	40	.....	.....	.....			1.52	+0.1	7	5,108	nw.	31	se.	4	13	7	10	5.1	0.0	0.0
South Pacific Coast Region.							**58.1**	**−0.5**												**75**	**2.88**	**+1.8**										**5.3**		
Fresno	327	89	98	29.64	30.00	+.01	59.3	−1.9	88	15	69	42	22	49	31	52	45	66			3.93	+3.2	10	5,181	nw.	32	nw.	21	13	6	11	4.7	0.0	0.0
Los Angeles	338	159	191	29.63	30.00	+.01	58.4	−1.0	72	15	65	47	19	52	20	53	49	76			1.97	+0.8	7	4,166	sw.	20	sw.	1	9	9	12	5.6	0.0	0.0
San Diego	87	62	70	29.90	29.99	.00	59.0	+0.5	69	5	64	48	23	54	16	54	52	80			1.05	+0.3	10	4,847	w.	25	w.	18	5	13	12	6.3	0.0	0.0
San Luis Obispo	201	32	40	29.82	30.04	−.01	55.6	+0.4	83	14	65	36	23	46	32	49	46	78			4.57	+3.1	10	3,377	nw.	20	w.	21	14	5	11	4.6	0.0	0.0
West Indies.																																		
San Juan, P. R.	82	9	54	29.92	30.01	.....	75.2	.....	87	25	81	67	15	70	17	.....	.....	.....			3.85	0.0	14	8,065	e.	33	e.	3	11	15	4	4.6	0.0	0.0
Panama Canal.																																		
Balboa Heights	118	7	97	29.74	29.86	+.01	81.1	−0.5	93	29	89	69	8	73	22	73	70	75			0.83	−2.0	2	7,640	nw.	29	nw.	30	4	26	0	5.2	0.0	0.0
Colon	36	7	97	29.84	29.88	+.01	81.7	+0.7	89	19	86	73	14	77	15	75	73	79			1.21	−3.0	15	10,832	n.	26	n.	1	7	17	6	5.4	0.0	0.0
Alaska.																																		
Juneau	80	11	54	29.78	29.87	.....	41.7	.....	57	4	48	28	4	35	29	38	33	76			5.44	.....	18	5,171	s.	28	se.	15	5	5	20	7.7	T.	0.0

TABLE II.—*Data furnished by the Canadian Meteorological Service, April, 1923.*

Stations.	Altitude above mean sea level, Jan. 1, 1919.	Pressure.			Temperature of the air.						Precipitation.		
		Station reduced to mean of 24 hours.	Sea level reduced to mean of 24 hours.	Departure from normal.	Mean max.+ mean min.÷2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Feet.	*In.*	*In.*	*In.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	*In.*	*In.*	*In.*
St. Johns, N. F.	125												
Sydney, C. B. I.	48	29.87	29.92	+.03	33.7	−1.3	40.8	26.6	59	0	3.40	−0.45	7.0
Halifax, N. S.	88	29.81	29.92	−.04	37.0	−0.8	44.5	29.4	64	12	3.39	−0.79	1.6
Yarmouth, N. S.	65	29.83	29.90	−.06	37.6	−1.3	43.8	31.5	60	15	5.28	+1.89	7.0
Charlottetown, P. E. I.	38	29.84	29.88	−.02	34.2	−1.0	40.5	28.0	58	8	1.08	−1.57	2.5
Chatham, N. B.	28	29.80	29.83	−.07	32.9	−2.6	42.1	23.8	59	−4	2.66	+0.03	5.3
Father Point, Que.	20	29.88	29.90	−.03	29.5	−3.7	37.6	21.5	60	0	2.54	+0.96	12.0
Quebec, Que.	296	29.59	29.93	−.06	33.1	−2.0	40.2	26.0	58	0	5.80	+3.71	18.6
Montreal, Que.	187	29.69	29.90	−.10	38.3	−1.4	46.7	30.0	76	2	4.28	+2.04	9.7
Stonecliffe, Ont.	489										1.66	−0.13	
Ottawa, Ont.	236	29.65	29.92	−.10	38.7	−1.3	48.3	29.2	82	−2	2.65	+1.15	2.6
Kingston, Ont.	285	29.61	29.93	−.09	38.7	−1.3	46.2	31.3	66	1			1.0
Toronto, Ont.	379	29.53	29.95	−.07	42.5	+1.7	51.1	33.9	81	5	2.32	−0.05	2.5
Cochrane, Ont.	930												
White River, Ont.	1,244	28.59	29.94	−.10	27.2	−5.8	44.3	10.2	72	−24	0.34	−0.91	3.1
Port Stanley, Ont.	592	29.34	30.00	−.02	39.0	−2.0	47.4	30.7	64	3	1.48	−0.99	2.1
Southampton, Ont.	656	29.22			36.4	−2.3	44.8	28.0	76	−4	2.56	+0.78	6.2
Parry Sound, Ont.	638	29.20	29.90	−.12	35.6	−2.0	45.0	26.2	76	−2	2.71	+0.80	4.2
Port Arthur, Ont.	644	29.24	29.96	−.07	33.2	−0.3	42.3	24.1	67	−6	0.33	−1.39	0.6
Winnipeg, Man.	760	29.13	29.98	−.04	34.1	−1.8	45.1	23.1	72	−9	0.73	−0.32	5.7
Minnedosa, Man.	1,690	28.12	29.98	−.03	29.0	−7.0	41.0	17.1	71	−14	1.14	+0.08	11.2
Le Pas, Man.	860				30.1		45.0	15.2	73	−14	0.10		1.0
Qu'Appelle, Sask.	2,115	27.64	29.91	−.08	35.9	−1.5	47.2	24.6	78	−6	1.66	+0.61	12.0
Medicine Hat, Alb.	2,144	27.59	29.86	−.06	45.7	+1.2	59.0	32.4	85	12	0.36	−0.38	2.3
Moose Jaw, Sask.	1,759				38.6		50.8	26.4	79	7	1.01		6.2
Swift Current, Sask.	2,392	27.34	29.94	−.02	40.2	−1.1	53.7	26.7	81	−2	0.51	−0.42	4.7
Calgary, Alb.	3,428												
Banff, Alb.	4,521	25.29	29.89	−.01	37.4	+2.1	52.1	22.7	76	−7	1.59	+0.51	13.7
Edmonton, Alb.	2,150												
Prince Albert, Sask.	1,450	28.39	29.99	+.01	35.7	−0.4	50.9	20.6	78	−11	1.16	+0.33	7.4
Battleford, Sask.	1,592	28.17	29.93	−.04	40.7	+3.5	55.1	26.4	85	0	0.54	+0.07	3.0
Kamloops, B. C.	1,262												
Victoria, B. C.	230	29.72	29.97	−.04	49.1	+2.3	55.6	42.6	70	39	0.70	−1.67	

SEISMOLOGICAL REPORTS FOR APRIL, 1923.

W. J. HUMPHREYS, Professor in Charge.

[Weather Bureau, Washington, June 3, 1923.]

TABLE 1.—*Noninstrumental earthquake reports, April, 1923.*

Day.	Approximate time, Greenwich civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
	H. m. s.	CALIFORNIA.	° ′	° ′			*Sec.*			
Apr. 1	4 19 22	Santa Rosa	38 30	122 45	1–2	1	1–2	None	Weak	M. W. Allen.
4	3 35 ..	Calipatria	33 08	115 30	2	Several.	Few.	Faint	Felt by many	J. S. Davis.
15	7 15 ..	Nevada City	39 15	121 00	3	1		None		B. H. Preston.
		WYOMING (LATE REPORTS).								
Mar. 24	4 00 ..	Elk	43 50	110 30	5	2		None	Felt by several	J. S. Chaplina.
		Kelly	43 40	110 40	6		40	Rumbling	13 shocks later, continuing until Apr. 12.	E. Russold.
		Kendall	43 10	110 00	2	1	30 *ca*	.....do	Felt by several	W. H. Showers; H. A. Cheeseman.

TABLE 2.—*Instrumental seismological reports, April, 1923.*

Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.

For significance of symbols and description of stations, see REVIEW for January, 1923.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
ALASKA. *U. S. C. & G. S. Magnetic Observatory, Sitka.*								
1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Apr. 10	.....	P_E	10 31 32	2	.....	.....	.....	Recorded on magnetograph.
		eP_N	10 31 41	.....	.....	.....	.....	
		L_E	10 31 50	8	.....	.....	.....	
		M_E	10 31 56	6	*400	.....	.....	
		C_E	10 32 17	.....	.....	.....	.....	
		F	10 35 ..	.....	.....	.....	.....	
13	.....	P_E	15 38 50	6	.....	.....	.....	
		e_E	15 42 59	11	.....	.....	.....	
		S_N	15 45 10	21	.....	.....	.....	
		L_E	15 47 03	24	.....	.....	.....	
		L_N	15 49 01	20	.....	.....	.....	
		M_E	15 51 44	17	$300	.....	.....	
		M_N	15 49 41	20	.....	*300	.....	
		F_E	16 20 ..	.....	.....	.....	.....	
		F_N	16 30 ..	.....	.....	.....	.....	
24	.....	P	22 45 06	.....	.....	.....	.....	Not very distant; tremors of 1 second period superposed on long period waves; felt in Sitka; recorded on magnetograph.
		L_E	22 45 48	12	.....	.....	.....	
		M_E	22 45 55	12	*1,500	.....	.....	
		iM_N	22 45 51	16	.....	*1,900	.....	
		C_E	22 46 05	4	.....	.....	.....	
		F_E	23 00 ..	.....	.....	.....	.....	
		F_N	22 55 ..	.....	.....	.....	.....	
25	.....	P	19 32 28	.....	.....	.....	.....	Tremors of less than 1 second period superposed on long waves: e_N is smooth; felt in Sitka; recorded on magnetograph.
		L_E	19 32 58	.....	.....	.....	.....	
		L_N	19 32 55	.....	.....	.....	.....	
		iM_E	19 33 16	13	*7,500	.....	.....	
		iM_N	19 33 09	14	.....	*6,600	.....	
		C_E	19 34 00	.....	.....	.....	.....	
		C_N	19 34 23	.....	.....	.....	.....	
		e_N	19 40 46	13	.....	.....	.....	
		F	19 47 ..	.....	.....	.....	.....	
25	.....	P	19 48 36	.....	.....	.....	.....	Same character as preceding; recorded on magnetograph.
		L	19 49 02	.....	.....	$300	.....	
		M_E	19 49 25	8	*600	.....	.....	
		F_E	19 55 ..	4	.....	.....	.....	
		F_N	20 00 ..	.....	.....	.....	.....	
CALIFORNIA. *Theosophical University, Point Loma.*								
1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Apr. 4	.....	.....	.....	.....	100	100	.....	Tremors during preceding 24 hours.
6	.....	.....	.....	.....	50	50	.....	
8	.....	.....	.....	.....	100	100	.....	
12	.....	.....	.....	.....	50	50	.....	
18	.....	.....	.....	.....	50	100	.....	
21	.....	.....	.....	.....	50	50	.....	
29	.....	.....	.....	.....	50	50	.....	
DISTRICT OF COLUMBIA. *U. S. Weather Bureau, Washington.*								
1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Apr. 13	.....	P?	15 42 26	.....	.....	.....	.....	
		S?	15 51 50	.....	.....	.....	.....	
		L	16 09 ..	.....	.....	.....	.....	
		L	16 12 ..	18	.....	.....	.....	
		F	16 50 ..	.....	.....	.....	.....	
19	.....	eL	4 19 ..	.....	.....	.....	.....	
		F	4 50 ..	.....	.....	.....	.....	
24	.....	e	23 02 ..	.....	.....	.....	.....	
		F	23 25 ..	.....	.....	.....	.....	
25	.....	e	19 39 ..	.....	.....	.....	.....	
		F	20 35 *ca*	.....	.....	.....	.....	
29	.....	e	2 45 ..	.....	.....	.....	.....	
		eL	2 52 ..	.....	.....	.....	.....	
		F	3 05 ..	.....	.....	.....	.....	
30	.....	e	16 33 ..	.....	.....	.....	.....	
		L	16 41 ..	15	.....	.....	.....	
		F	17 15 *ca*	.....	.....	.....	.....	
HAWAII. *U. S. C. & G. S. Magnetic Observatory, Honolulu.*								
1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Apr. 13	.....	P	10 19 17	.....	.....	.....	.....	Nothing definite.
		F_E	19 29 ..	.....	.....	.....	.....	
		F_N	19 23 ..	.....	.....	.....	.....	

* Trace amplitude.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
HAWAII. *U. S. C. & G. S. Magnetic Observatory, Honolulu*—Contd.								
1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Apr. 13	.....	P_N	15 39 30	.....	.....	.....	.....	
		iS_N	15 46 13	.....	.....	.....	.....	
		$SR1_N$	15 49 29	.....	.....	.....	.....	
		L_N	15 52 10	25	.....	150	.....	
		M_N	15 53 52	.....	.....	.....	.....	
		F_N	16 22 ..	.....	.....	.....	.....	
19	.....	e_E	3 32 51	.....	.....	.....	.....	Nothing definite
		e_N	3 32 10	.....	.....	.....	.....	
		F_E	4 28 ..	.....	.....	.....	.....	
		F_N	4 17 ..	.....	.....	.....	.....	
29	.....	e_E	2 46 20	.....	.....	.....	.....	
		e_N	2 45 42	.....	.....	.....	.....	
		M_E	2 48 18	8	14	.....	.....	
		M_N	2 47 25	8	.....	18	.....	
		F_E	2 56 ..	.....	.....	.....	.....	
		F_N	2 55 ..	.....	.....	.....	.....	
ILLINOIS. *U. S. Weather Bureau, Chicago.*								
1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Apr. 13	.....	e	10 26 50?	.....	.....	.....	.....	
		S?	10 30 50	.....	.....	.....	.....	
		F	12 20 *ca.*	.....	.....	.....	.....	
13	.....	P	15 41 30	.....	.....	.....	7,900	
		S	15 50 35	.....	.....	.....	.....	
		i	15 58 10	.....	.....	.....	.....	
		L	16 04 45	30	.....	.....	.....	
		L	17 30 ..	18	.....	.....	.....	
		F	18 30 *ca.*	.....	.....	.....	.....	
14	.....	eL	15 52 ..	.....	.....	.....	.....	
		F	16 30 *ca.*	.....	.....	.....	.....	
19	.....	i	3 31 44	.....	.....	.....	.....	
		L	4 07 ..	.....	.....	.....	.....	
		L	4 12 ..	33	.....	.....	.....	
		L	4 18 ..	24	.....	.....	.....	
		F	5 30 *ca.*	.....	.....	.....	.....	
23	.....	P	3 41 28	.....	.....	.....	9,100	
		S?	3 51 43	.....	.....	.....	.....	
		eL	4 07 10	20	.....	.....	.....	
		F	5 20 *ca.*	.....	.....	.....	.....	
24	.....	P	22 51 50	.....	.....	.....	4,000	
		S	22 57 28	.....	.....	.....	.....	
		L?	23 01 52	.....	.....	.....	.....	
		F	23 40 ..	.....	.....	.....	.....	Micros.
25	.....	P	19 38 57	.....	.....	.....	4,100	
		S	19 44 40	.....	.....	.....	.....	
		L	19 49 20	.....	.....	.....	.....	
		F	21 *ca.*	.....	.....	.....	.....	
29	.....	P	2 37 15	.....	.....	.....	4,000	
		S	2 41 54	.....	.....	.....	.....	
		L?	2 45 00	.....	.....	.....	.....	
		F	3 30 *ca.*	.....	.....	.....	.....	
29	.....	e	9 57 ..	.....	.....	.....	.....	
		L	10 17 ..	.....	.....	.....	.....	
		L	10 23 ..	18	.....	.....	.....	
		F	10 58 *ca.*	.....	.....	.....	.....	
MARYLAND. *U. S. C. & G. S. Magnetic Observatory, Cheltenham.*								
1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Apr. 13	.....	e_E	16 00 31	.....	.....	.....	.....	Nothing on NS.
		L_E	16 09 27	26	.....	.....	.....	
		M_E	17 20 14	17	*100	.....	.....	
		F_E	17 30 ..	.....	.....	.....	.....	
24	.....	e	23 07 08	3	.....	.....	.....	Has characteristics of nearby quake, but reported local at Sitka.
		M	23 07 22	3	*200	*200	.....	
		F	23 13 ..	.....	.....	.....	.....	
25	.....	e_E	19 54 18	5	.....	.....	.....	Do.
		e_N?	19 54 01	.....	.....	.....	.....	
		e_N	19 54 47	4	.....	.....	.....	
		M_E	19 55 02	.....	*200	.....	.....	
		M_N	19 55 06	.....	.....	*200	.....	
		F	20 02 ..	.....	.....	.....	.....	

* Trace amplitude.

TABLE 2.—*Instrumental seismological reports, April, 1923*—Continued.

CANAL ZONE. *Panama Canal, Balboa Heights.*

25 KILOGRAM RECORD.

1923.			H. m. s.	Sec.	μ	μ	Km.	
Apr. 24	.....	.....	.....	.....	.....	.....	.....	Slight tremors between 8:53 and 8:56: distance and direction unknown.
31	.....	S_E....	19 17 14	.....	.....	.....	.....	Probably NW; distance about 350 km.
		S_N....	19 17 12	.....	.....	.....	.....	
		L_N....	19 17 34	.....	.....	.....	.....	
		M_E....	19 17 40	.....	*500	.....	.....	Very slight tremors also recorded on 28th, 29th, and 30th.
		M_N....	19 17 38	.....	.....	*1,000	.....	
		F_E....	19 21 00	.....	.....	.....	.....	
		F_N....	19 21 40	.....	.....	.....	.....	

100 KILOGRAM RECORD.

Apr. 24	.....	.....	.....	.....	.....	.....	.....	Slight tremors between 8:53 and 8:56. Distance and direction unknown.
28	.....	.....	.....	.....	.....	.....	.....	Slight tremors between 10:08:48 and 10:11:00.
29	.....	.....	.....	.....	.....	.....	.....	Slight tremors between 11:22:18 and 11:27:00.
30	.....	.....	.....	.....	.....	.....	.....	Slight tremors between 12:00:45 and 12:06:00.
31	.....	P.....	19 16 32	.....	.....	.....	.....	Probably NW; distance, about 350 km.
		S.....	19 17 10	.....	.....	.....	.....	
		L_E....	19 17 32	.....	.....	.....	.....	
		L_N....	19 17 30	.....	.....	.....	.....	
		M_E....	19 17 35	.....	*1,500	.....	.....	
		M_N....	19 17 36	.....	.....	*2,500	.....	
		F_E....	19 24 15	.....	.....	.....	.....	
		F_N....	19 24 45	.....	.....	.....	.....	

VERMONT. *U. S. Weather Bureau, Northfield.*

1923.			H. m. s.	Sec.	μ	μ	Km.
Apr. 13	.....	L.....	16 08 ..	.....	.....	.....	.....
		L.....	16 10 ..	18	.....	.....	.....
		F.....	16 30 ..	.....	.....	.....	.....
24	.....	e.....	22 57 ..	.....	.....	.....	.....
		L.....	23 06 30	.....	.....	.....	.....
25	.....	F.....	00 15 ..	.....	.....	.....	.....
25	.....	e.....	19 50 ..	.....	.....	.....	.....
		F.....	20 30 ..	.....	.....	.....	.....

CANADA. *Dominion Observatory, Ottawa.*

INSTRUMENTS—DETERMINED CONSTANTS.

Instrument.	To—	r.	v.	e	Comp.	l.	Determined.
I.....	5.5	.....	120	2:1	NS.	.....	Apr. 4, 1923.
II.....	5.8	.....	120	18:1	EW.	.....	Do.
17.....	12.0	.....	250	20:1	EW.	.....	Do.
23.....	12.0	.....	250	10:1	EW.	.....	Do.
D.....	37.2	.....	.....	13:10	EW.	.....	Feb. 7, 1923.
D.....	36.1	.....	.....	13:10	NS.	.....	Do.
W.....	6.0	6 mm.	160	20:1	V.	.....	Apr. 4, 1923.

1923.			H. m. s.	Sec.	μ	μ	Km.	
Apr. 5	.....	eL.....	(23 00) ...	.....	.....	.....	.....	Halation trouble; times uncertain.
		L.....	(23 06) ...	.....	.....	.....	.....	
		F.....	(23 20) ...	.....	.....	.....	.....	
13	.....	e.....	10 26 26	.....	.....	.....	.....	Small amplitudes and irregular periods.
		e.....	10 27 58	.....	.....	.....	.....	
		e.....	10 33 16	.....	.....	.....	.....	
		i or eL.	10 36 08	.....	.....	.....	.....	
		L.....	11 20 ..	.....	.....	.....	.....	
		eL.....	12 00 ..	.....	.....	.....	.....	
		F.....	12 25 ..	.....	.....	.....	.....	
13	.....	O.....	15 31 12	.....	.....	.....	7,380	
		PM...	15 42 00	.....	.....	.....	.....	
		S.....	15 50 48	.....	.....	.....	.....	
		SR2...	15 58 20	.....	.....	.....	.....	
		eL?...	16 02 ..	.....	.....	.....	.....	
		M1-17.	16 09 ..	17	110	.....	.....	
		M2-17.	16 13 ..	22	275	.....	.....	
		M3-17.	16 15 ..	19	195	.....	.....	
		M4-17.	16 17 ..	17	140	.....	.....	
		L.....	16 20 *to*	17	.....	.....	.....	
			18 00 ..	10	.....	.....	.....	
		F.....	18 40 ..	.....	.....	.....	.....	

*Trace amplitude.

CANADA. *Dominion Observatory, Ottawa*—Continued.

1923.			H. m. s.	Sec.	μ	μ	Km.	
Apr. 13	.....	eL.....	21 16 30	.....	.....	.....	.....	
			to 26 ..	.....	.....	.....	.....	
		F.....	21 37 ..	.....	.....	.....	e..	
14	.....	eL-17.	9 31 30	.....	.....	.....	.....	
			to 44 ..	.....	.....	.....	.....	
		F.....	9 50 *ca.*	.....	.....	.....	.....	
14	.....	eL.....	15 57	.....	.....	.....	.....	
		L.....	16 00 *to*	.....	.....	.....	.....	
		F.....	16 08 ..	.....	.....	.....	.....	Lost in micros.
19	.....	e.....	3 31 41	.....	.....	.....	.....	
		eL?...	3 51 ..	.....	.....	.....	.....	
		L.....	4 05 ..	45	.....	.....	.....	
		L.....	4 12 ..	32	.....	.....	.....	
		L.....	4 25 ..	22	.....	.....	.....	
		L.....	4 39 30	.....	.....	.....	.....	
		L.....	4 50 ..	.....	.....	.....	.....	
		L.....	5 03 ..	.....	.....	.....	.....	
		F.....	5 45 ..	.....	.....	.....	.....	
23	.....	O.....	3 33 48	.....	.....	.....	5,580	P and S very faint
		P.....	3 42 53	.....	.....	.....	.....	
		S.....	3 50 07	.....	.....	.....	.....	
		eL.....	3 58 30	.....	.....	.....	.....	
		L.....	4 04 ..	45	.....	.....	.....	
		L.....	4 10 ..	30	.....	.....	.....	
		M.....	4 16 ..	17	26	.....	.....	
		L.....	4 24 ..	14	.....	.....	.....	
		L.....	4 31 ..	11	.....	.....	.....	
		F.....	5 25 ..	.....	.....	.....	.....	
24	.....	e(S)...	22 58 15	.....	.....	.....	4,300?	Very irregular periods.
		eL.....	23 04 ..	.....	.....	.....	.....	
		M.....	23 05 30	.....	.....	.....	.....	
		F.....	23 37 ..	.....	.....	.....	.....	
25	.....	O.....	19 31 46	.....	.....	.....	4,300	Irregular periods similar to preceding quake.
		P.....	19 39 26	.....	.....	.....	.....	
		S.....	19 45 30	.....	.....	.....	.....	
		eL.....	19 50 30	.....	.....	.....	.....	
		M.....	19 52 30	.....	.....	.....	.....	
		L.....	19 55 ..	.....	.....	.....	.....	
		L.....	20 07 30	.....	.....	.....	.....	
		F.....	20 50 ..	.....	.....	.....	.....	
27	.....	e.....	10 49 ..	.....	.....	.....	.....	
		eL.....	11 05 30	.....	.....	.....	.....	
		L.....	11 33 ..	25	.....	.....	.....	
		F.....	12 06 ..	.....	.....	.....	.....	
29	.....	O.....	2 31 08	.....	.....	.....	3,900	
		P.....	2 38 19	.....	.....	.....	.....	
		S.....	2 44 00	.....	.....	.....	.....	
		eL?...	2 49 30	.....	.....	.....	.....	Small amplitudes.
		L.....	2 51 42	.....	.....	.....	.....	
		M.....	2 54 24	12	12	.....	.....	
		F.....	3 35 *ca*	.....	.....	.....	.....	
29	.....	e?.....	9 46 24	.....	.....	.....	.....	
		eL.....	9 56 30	.....	.....	.....	.....	
		L.....	10 10 ..	30	.....	.....	.....	Sinusoidal L waves of small amplitude.
		L.....	10 19 ..	21	.....	.....	.....	
		L.....	10 24 ..	18	.....	.....	.....	
		L.....	10 27 ..	16	.....	.....	.....	
		F.....	10 44 *ca*	.....	.....	.....	.....	
29	.....	eL.....	19 33 ..	.....	.....	.....	.....	Traces on Milne-Shaw only.
		L.....	19 35 ..	23	.....	.....	.....	
		F.....	19 43 ..	.....	.....	.....	.....	
30	.....	e?.....	16 37 30	.....	.....	.....	.....	
		eL.....	16 43 ..	.....	.....	.....	.....	
		F.....	17 05 ..	.....	.....	.....	.....	
30	.....	eL.....	20 55 ..	.....	.....	.....	.....	
		L.....	20 58 ..	23	.....	.....	.....	
		L.....	21 11 30	.....	.....	.....	.....	
		F.....	21 20 ..	.....	.....	.....	.....	

CANADA. *Dominion Meteorological Service, Toronto.*

1923.			H. m. s.	Sec.	μ	μ	Km.	
Apr. 13	.....	L.....	13 36 00	.....	*100	.....	.....	
		F.....	13 42 48	.....	.....	.....	.....	
13	.....	S?.....	15 52 42	.....	.....	.....	.....	P indistinct.
		i.....	15 59 36	.....	.....	.....	.....	
		eL.....	16 03 54	.....	.....	.....	.....	
		iL.....	16 08 06	.....	.....	.....	.....	
		M.....	16 14 48	.....	*2000	.....	.....	
		M2.....	16 16 48	.....	*2000	.....	.....	
		eL.....	16 27 42	.....	.....	.....	.....	
		M.....	16 31 36	.....	*700	.....	.....	
		F.....	17 40 42	.....	.....	.....	.....	
13	.....	L.....	21 16 00	.....	*50	.....	.....	
19	.....	L.....	4 00 00	.....	.....	.....	.....	
		L.....	4 22 30	.....	.....	.....	.....	
		eL.....	4 33 06	.....	.....	.....	.....	
		M.....	4 39 06	.....	*400	.....	.....	
		F.....	5 22 42	.....	.....	.....	.....	

*Trace amplitude.

TABLE 2.—*Instrumental seismological reports, April, 1923*—Continued.

CANADA. *Dominion Meteorological Service, Toronto*—Continued.

1923.			H. m. s.	Sec.	μ	μ	Km.	
Apr. 23	.....	eL.....	4 15 30	.....	.....	.....	.....	P and S not recorded.
		M.....	4 19 42	.....	*300	.....	.....	
		eL.....	4 21 30	.....	.....	.....	.....	
		eL.....	4 25 36	.....	.....	.....	.....	
		eL.....	4 38 36	.....	.....	.....	.....	
		F.....	5 27 36	.....	.....	.....	.....	
24	.....	iL.....	23 04 48	.....	*100	.....	.....	
		F.....	23 16 06	.....	.....	.....	.....	
25	.....	e.....	19 50 48	.....	.....	.....	.....	
		eL.....	19 52 30	.....	.....	.....	.....	
		M.....	19 52 48	.....	*300	.....	.....	
		eL.....	20 06 54	.....	.....	.....	.....	
		F.....	20 22 30	.....	.....	.....	.....	
29	.....	L.....	3 14 03	.....	*100	.....	.....	
		F.....	3 18 54	.....	.....	.....	.....	
30	.....	L.....	16 41 36	.....	.....	.....	.....	
		F.....	17 14 00	.....	*100	.....	.....	
30	.....	L.....	21 00 36	.....	*100	.....	.....	
		F.....	21 18 36	.....	.....	.....	.....	

CANADA. *Dominion Meteorological Service, Victoria.*

1923.			H. m. s.	Sec.	μ	μ	Km.	
Apr. 3	.....	L.....	18 14 23	25	.....	.....	.....	
		M.....	18 21 13	25	.....	2	.....	
		F.....	18 28 28	.....	.....	.....	.....	
13	.....	L.....	10 25 47	12	.....	.....	.....	
		M.....	10 26 26	8	2	.....	.....	
		F.....	10 43 35	.....	.....	.....	.....	
		L.....	10 25 51	12	.....	.....	.....	
		M.....	10 26 32	8	.....	9	.....	
		F.....	10 51 40	.....	.....	.....	.....	
13	.....	P.....	15 39 11	5	.....	.....	.....	Kamchatka.
		S.....	15 45 41	18	.....	.....	.....	
		L.....	15 52 46	26	.....	.....	.....	
		M.....	15 55 31	22	55	.....	4,779	
		F.....	18 40 06	.....	.....	.....	.....	
		P.....	15 39 11	5	.....	.....	.....	
		S.....	15 45 47	18	.....	.....	.....	
		L.....	15 52 26	30	.....	.....	.....	
		M.....	15 54 56	22	.....	62	4,880	
		F.....	18 26 04	.....	.....	.....	.....	
13	.....	L.....	21 01 33	22	.....	.....	.....	
		M.....	21 10 19	11	2	.....	.....	
		F.....	21 19 48	.....	.....	.....	.....	
		L.....	21 02 16	22	.....	.....	.....	
		M.....	21 10 59	11	.....	2	.....	
		F.....	21 13 56	.....	.....	.....	.....	
19	.....	P.....	3 35 37	5	.....	.....	.....	
		S.....	3 38 15	10	.....	.....	.....	
		L.....	3 47 40	20	.....	.....	.....	
		M.....	4 01 20	24	25	.....	1,510	
		F.....	4 57 40	.....	.....	.....	.....	
		P.....	3 35 30	7	.....	.....	1,560	
		S.....	3 38 13	10	.....	.....	.....	
		L.....	3 47 37	.....	.....	.....	.....	
		F.....	4 58 02	.....	.....	.....	.....	
23	.....	P.....	3 29 31	7	.....	.....	.....	
		S.....	3 39 38	11	.....	.....	.....	
		L.....	4 00 54	23	.....	.....	.....	
		M.....	4 07 08	15	5	.....	8,940	
		F.....	5 19 44	.....	.....	.....	.....	
		P.....	3 29 24	6	.....	.....	.....	
		S.....	3 39 37	11	.....	.....	.....	
		M.....	4 12 28	12	.....	4	9,040	
		F.....	5 14 15	.....	.....	.....	.....	
24	.....	P.....	22 47 50	6	.....	.....	.....	Felt at Atlin, 22:45.
		L.....	22 50 47	30	.....	.....	.....	
		M.....	22 53 33	12	19	.....	1,710	
		F.....	23 28 00	.....	.....	.....	.....	
		P.....	22 47 45	6	.....	.....	.....	
		L.....	22 50 50	26	.....	.....	.....	
		M.....	22 53 20	11	.....	11	.....	
		F.....	23 35 30	.....	.....	.....	.....	
25	.....	P.....	19 35 04	6	.....	.....	.....	Felt at Atlin, 19:30.
		L.....	19 37 42	25	.....	.....	.....	
		M.....	19 40 42	11	29	.....	1,510	
		F.....	20 48 50	.....	.....	.....	.....	
		P.....	19 35 04	6	.....	.....	.....	
		L.....	19 37 49	27	.....	.....	.....	
		M.....	19 40 42	14	.....	46	1,580	
		F.....	20 46 52	.....	.....	.....	.....	

*Trace amplitude.

CANADA. *Dominion Meteorological Service, Victoria*—Continued.

1923.			H. m. s.	Sec.	μ	μ	Km.	
Apr. 29	.....	P.....	2 33 27	6	.....	.....	.....	
		L.....	2 34 51	26	.....	.....	.....	
		M.....	2 37 02	15	29	.....	770	
		F.....	3 35 39	.....	.....	.....	.....	
		P.....	2 33 15	6	.....	.....	1,020	
		L.....	2 35 05	26	.....	.....	.....	
		M.....	2 37 35	11	.....	24	.....	
		F.....	3 46 47	.....	.....	.....	.....	
29	.....	P.....	9 48 55	6	.....	.....	.....	
		L.....	10 16 33	26	.....	.....	.....	
		M.....	10 28 25	22	4	.....	.....	
		F.....	10 49 00	.....	.....	.....	.....	
		P.....	9 48 55	6	.....	.....	.....	
		L.....	10 26 02	26	.....	.....	.....	
		M.....	10 34 48	16	.....	2	.....	
30	.....	L.....	16 50 30	20	.....	.....	.....	
		M.....	16 52 54	14	2	.....	.....	
		P.....	16 43 35	5	.....	.....	.....	
		L.....	16 50 33	15	.....	.....	.....	
		M.....	16 55 23	10	.....	1	.....	
30	.....	L.....	20 36 20	25	.....	.....	.....	NS too small to measure.
		M.....	20 43 38	14	1	.....	.....	

Period: 12 secs.; magnification, 250; damping, 20:1.

No earthquakes were recorded during April, 1923, at the following stations:

COLORADO. *Regis College*, Denver.

Reports for April, 1923, have not been received from the following stations:

ALABAMA. *Spring Hill College*, Mobile.

ARIZONA. *U. S. C. & G. S. Magnetic Observatory*, Tucson.

DISTRICT OF COLUMBIA. *Georgetown University*, Washington.

MASSACHUSETTS. *Harvard University*, Cambridge.

MISSOURI. *St. Louis University*, St. Louis.

NEW YORK. *Cornell University*, Ithaca; *Fordham University*, New York.

PORTO RICO. *U. S. C. & G. S. Magnetic Observatory*, Vieques.

TABLE 3.—*Late reports (instrumental).*

DISTRICT OF COLUMBIA. *Georgetown University, Washington.*

1923.			H. m. s.	Sec.	μ	μ	Km.	
Feb. 2	.....	eP.....	5 19 16	.....	.....	.....	.....	Micros.
		eS.....	5 29 ..	.....	.....	.....	.....	
		L_E.....	5 47 22	19	.....	.....	.....	
		L_N.....	5 49 22	22	.....	.....	.....	
		M_E.....	5 51 07	.....	*1,200	.....	.....	
		F.....	7 10 ..	.....	.....	.....	.....	
			VERTICAL.					
		eP_Z.....	5 19 23	.....	.....	.....	.....	S_Z not clear.
		L.....	5 51 ..	21	.....	.....	.....	
		F.....	7 15 ..	.....	.....	.....	.....	
3	.....	eP_E.....	16 13 20	.....	.....	.....	.....	
		eP_N.....	16 13 21	.....	.....	.....	.....	
		iS_E.....	16 22 55	.....	.....	.....	.....	
		eS_N.....	16 22 55	.....	.....	.....	.....	
		eL_E.....	16 31 54	26	.....	.....	.....	
		eL_N.....	16 31 54	18	.....	.....	.....	
		L_E.....	16 39 ..	37	.....	.....	.....	
		L_N.....	16 40 ..	33	.....	.....	.....	
		M_E1.....	16 43 43	22	*20,800	.....	.....	
		M_N1.....	16 48 54	19	.....	*26,600	.....	
		M_E2.....	16 48 35	22	*31,100	.....	.....	
		M_E3.....	16 53 38	19	*16,400	.....	.....	
		M_N2.....	16 55 04	20	.....	*18,500	.....	
		M_E4.....	16 56 39	.....	*11,600	.....	.....	
		M_N3.....	17 00 21	19	.....	*6,500	.....	
		M_E5.....	17 00 09	15	*9,000	.....	.....	
		M_E6.....	17 28 06	21	.....	.....	.....	
		F.....	.....	.....	.....	.....	.....	Lost in next quake.
3	.....	eP_E.....	18 54 40	.....	.....	.....	.....	Sheets off at 20h.; quakes still on.
		eP_N.....	18 54 37	.....	.....	.....	.....	
		iS_E.....	19 02 22	.....	.....	.....	.....	
		iS_N.....	19 02 24	.....	.....	.....	.....	
		eL.....	19 10 30	.....	.....	.....	.....	
		L_E.....	19 21 ..	22	.....	.....	.....	
		L_N.....	19 21 ..	26	.....	.....	.....	

*Trace amplitude.

TABLE 3.—*Lake reports (instrumental)*—Continued.

DISTRICT OF COLUMBIA. *Georgetown University, Washington*—Contd.

1923.			H. m. s.	Sec.	μ	μ	Km.	
Feb. 3	.....	eP_E...	17 51 52	.....	.....	.....	.....	Rest of quake in cauda of first; no more phases discernible.
		eP_N...	17 51 54	.....	.....	.....	.....	
		eS_E...	18 02 10	.....	.....	.....	.....	
		eS_N...	18 02 05	.....	.....	.....	.....	
8	.....	iP_E...	0 39 33	.....	.....	.....	.....	All phases except P doubtful; heavy micros.
		eP_N...	0 39 33	.....	.....	.....	.....	
		eS_E?..	0 44 05	.....	.....	.....	.....	
		eS_N?..	0 45 59	.....	.....	.....	.....	
		eL_E?..	0 50 00	.....	.....	.....	.....	
		F?....	1 20 ..	.....	.....	.....	.....	
11	.....	e_E....	22 57 ..	.....	.....	.....	.....	Heavy micros; difficult to read.
		e_N....	22 56 49	.....	.....	.....	.....	
		eL_E...	23 27 30	16	.....	.....	.....	
		eL_N...	23 27 12	16	.....	.....	.....	
		L_E....	23 34 11	16	.....	.....	.....	
		L_N....	23 34 11	16	.....	.....	.....	
		F.....	24 *ca.*	.....	.....	.....	.....	
12	.....	eP.....	2 10 14	.....	.....	.....	.....	Heavy micros.
		eS_N?..	2 19 22	.....	.....	.....	.....	
		eL_E?..	2 37 18	21	.....	.....	.....	
		L_E....	2 44 11	16	.....	.....	.....	
		L_N....	2 45 26	16	.....	.....	.....	
		F.....	3 00 ..	.....	.....	.....	.....	
12	.....	e_E....	13 47 13	.....	.....	.....	.....	Possibly not seismic; very heavy micros.
		e_N....	13 47 29	.....	.....	.....	.....	
		eS_E...	13 53 13	.....	.....	.....	.....	
		eS_N...	13 53 13	.....	.....	.....	.....	
		F.....	14 05 ..	.....	.....	.....	.....	
24	.....	eP_E...	7 46 12	.....	.....	.....	.....	Heavy micros.
		iP_N...	7 46 12	.....	.....	.....	.....	
		S.....	7 55 33	.....	.....	.....	.....	
		S.....	7 55 34	.....	.....	.....	.....	
		eL.....	8 08 00	.....	.....	.....	.....	
		L.....	8 13 16	26	.....	.....	.....	
		M_E1..	8 14 20	18	*2,200	.....	.....	
		M_N1..	8 18 41	17	.....	*1,700	.....	
		M_E2...	8 19 26	16	*2,400	.....	.....	
		M_E3...	8 21 43	15	*1,700	.....	.....	
		F.....	9 35 ..	.....	.....	.....	.....	
27	.....	eP_N...	20 44 22	.....	.....	.....	.....	P difficult; EW difficult to interpret. Heavy micros.
		S_N....	20 49 43	.....	.....	.....	.....	
		F.....	21 10 ..	.....	.....	.....	.....	

NEW YORK. *Cornell University, Ithaca.*

1922.			H. m. s.	Sec.	μ	μ	Km.	
Dec. 15	.....	L.....	0 09 ..	20	.....	.....	.....	
		F.....	0 23 ..	.....	.....	.....	.....	
18	.....	eP_N...	12 40 24	.....	.....	.....	.....	
		S.....	12 44 45	.....	.....	.....	.....	
		eL.....	12 47 ..	.....	.....	.....	.....	
		L.....	12 47 30	20	.....	.....	.....	
		L.....	12 52 ..	14	.....	.....	.....	
		L.....	12 54 ..	13	.....	.....	.....	
		F.....	13 33 ..	.....	.....	.....	.....	
31	.....	L.....	8 06 ..	22	.....	.....	.....	
		L.....	8 10 ..	24	.....	.....	.....	
		L.....	8 15 ..	20	.....	.....	.....	
		F.....	8 37 ..	.....	.....	.....	.....	
1923.								
Jan. 22	.....	P.....	9 11 18	.....	.....	.....	.....	
		iS.....	9 16 57	.....	.....	.....	.....	
		M_N...	9 25 ..	14	.....	.....	.....	
		F.....	10 56 ..	.....	.....	.....	.....	
27	.....	e.....	8 11 06	.....	.....	.....	.....	
		e.....	8 13 ..	.....	.....	.....	.....	
		L.....	8 14 30	12	.....	.....	.....	
		F.....	8 55 ..	.....	.....	.....	.....	
Feb. 2	.....	L.....	1 43 ..	24	.....	.....	.....	Records damaged.
		F.....	2 08 ..	.....	.....	.....	.....	
2	.....	eP.....	6 19 00	.....	.....	.....	.....	Do.
		e.....	5 23 25	.....	.....	.....	.....	
		eS.....	5 28 10	.....	.....	.....	.....	
		e.....	5 32 48	.....	.....	.....	.....	
		e.....	5 36 ..	14	.....	.....	.....	
		L.....	5 45 ..	22	.....	.....	.....	
		F.....	7 36 ..	.....	.....	.....	.....	
3	.....	eP.....	16 13 08	.....	.....	.....	.....	
		S.....	16 22 26	.....	.....	.....	.....	
		SR1...	16 27 41	.....	.....	.....	.....	
		SR2...	16 30 40	.....	.....	.....	.....	
		L.....	16 33 30	45	.....	.....	.....	
		L.....	16 41 ..	21	.....	.....	.....	
		L.....	16 43 ..	18	.....	.....	.....	
		L.....	16 46 ..	19	.....	.....	.....	
		L.....	16 48 ..	16	.....	.....	.....	
		L.....	16 51 ..	17	.....	.....	.....	
		L.....	16 53 ..	16	.....	.....	.....	
		L.....	16 56 ..	18	.....	.....	.....	
		L.....	17 00 ..	17	.....	.....	.....	

* Trace amplitude.

NEW YORK. *Cornell University, Ithaca*—Continued.

1923.			H. m. s.	Sec.	μ	μ	Km.
Feb. 3	.....	L.....	17 22 ..	17	.....	.....	.....
		L.....	17 26 ..	20	.....	.....	.....
		L.....	17 34 ..	16	.....	.....	.....
		L.....	17 41 ..	17	.....	.....	.....
		L.....	19 20 ..	24	.....	.....	.....
		F.....	21 23 ..	.....	.....	.....	.....
8	.....	e.....	0 39 48	.....	.....	.....	.....
		e.....	0 45 ..	.....	.....	.....	.....
		e.....	0 52 ..	.....	.....	.....	.....
		e.....	0 55 24	.....	.....	.....	.....
		F.....	1 22 ..	.....	.....	.....	.....
12	.....	e.....	2 23 42	.....	.....	.....	.....
		L.....	2 36 ..	22	.....	.....	.....
		F.....	3 07 ..	.....	.....	.....	.....
23	.....	i.....	6 14 32	7	.....	.....	.....
		F.....	6 34 ..	.....	.....	.....	.....
24	.....	e.....	7 45 58	.....	.....	.....	.....
		S.....	7 55 00	.....	.....	.....	.....
		e.....	7 59 30	.....	.....	.....	.....
		e.....	8 02 53	.....	.....	.....	.....
		eL.....	8 08 ..	.....	.....	.....	.....
		L.....	8 10 ..	22	.....	.....	.....
		L.....	8 13 42	17	.....	.....	.....
		F.....	9 51 ..	.....	.....	.....	.....
27	.....	e.....	20 44 13	.....	.....	.....	.....
		eL.....	20 50 48	7	.....	.....	.....
		L.....	20 51 30	8	.....	.....	.....
		F.....	21 17 ..	.....	.....	.....	.....
Mar. 2	.....	e?.....	17 11 26	.....	.....	.....	.....
		e.....	17 20 ..	.....	.....	.....	.....
		e.....	17 27 ..	.....	.....	.....	.....
		L.....	17 51 ..	30	.....	.....	.....
		L.....	17 54 ..	24	.....	.....	.....
		F.....	18 41 ..	.....	.....	.....	.....
11	.....	L.....	23 25 ..	.....	.....	.....	.....
		F.....	23 36 ..	.....	.....	.....	.....
15	.....	e.....	6 08 32	.....	.....	.....	.....
		i.....	6 08 48	.....	.....	.....	.....
		e.....	6 12 54	.....	.....	.....	.....
		L.....	6 16 ..	20	.....	.....	.....
		F.....	6 28 ..	.....	.....	.....	.....
16	.....	L.....	23 11 ..	23	.....	.....	.....
		F.....	23 43 ..	.....	.....	.....	.....
18	.....	e.....	20 44 ..	.....	.....	.....	.....
		F.....	20 52 ..	.....	.....	.....	.....
24	.....	e.....	13 06 ..	.....	.....	.....	.....
		e.....	13 18 ..	.....	.....	.....	.....
		L.....	13 31 ..	.....	.....	.....	.....
		L.....	13 37 ..	31	.....	.....	.....
		F.....	14 21 ..	.....	.....	.....	.....

CANADA. *Dominion Meteorological Service, Toronto.*

1923.			H. m. s.	Sec.	μ	μ	Km.	
Mar. 1	.....	i.....	?8 48 30	.....	.....	.....	.....	P and S not recorded.
		L.....	8 56 42	.....	.....	.....	.....	
		eL.....	8 59 30	.....	.....	.....	.....	
		L.....	9 01 18	.....	.....	.....	.....	
		M.....	9 03 18	.....	*600	.....	.....	
		F.....	10 10 30	.....	.....	.....	.....	
2	.....	S.....	17 10 12	.....	.....	.....	.....	
		e.....	17 28 06	.....	.....	.....	.....	
		L.....	17 41 36	.....	.....	.....	.....	
		iL.....	17 46 24	.....	.....	.....	.....	
		eL.....	18 00 18	.....	.....	.....	.....	
		eL.....	18 06 48	.....	.....	.....	.....	
		M.....	18 11 12?	.....	*800	.....	.....	Maximum may have come in after 18:18; attending instrument.
		eL.....	18 14 06	.....	.....	.....	.....	
		F.....	19 28 48	.....	.....	.....	.....	
3	.....	L.....	22 36 42 to 23 20 00	.....	*50	.....	.....	
4	.....	L.....	7 52 30	.....	.....	.....	.....	
		L.....	7 54 42	.....	.....	.....	.....	
		L.....	8 10 00	.....	.....	.....	.....	
		M.....	8 17 06	.....	*200	.....	.....	
		F.....	10 02 00	.....	.....	.....	.....	
11	.....	L.....	23 26 3	.....	.....	.....	.....	
		L.....	23 28 48	.....	.....	.....	.....	
		M.....	23 29 42 8	.....	*200	.....	.....	
12		F.....	0 01 00	.....	.....	.....	.....	
12	.....	L.....	9 59 42	.....	*100	.....	.....	
		F.....	10 02 42	.....	.....	.....	.....	
12	.....	L.....	10 19 00	.....	.....	.....	.....	
		L.....	10 51 30	.....	*50	.....	.....	
		F.....	11 13 42	.....	.....	.....	.....	

* Trace amplitude.

TABLE 3.—*Lake reports (instrumental)*—Continued.

CANADA. *Dominion Meteorological Service, Toronto*—Continued.

1923.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Mar. 12	.....	L.....	12 06 48	.....	.....	.....	.....	
		L.....	12 20 36	.....	.....	.....	.....	
		iL.....	12 35 12	.....	.....	.....	.....	
		M.....	12 35 30	.....	*200	.....	.....	
		eL.....	12 59 42	.....	.....	.....	.....	
		F.....	13 26 18	.....	.....	.....	.....	
13	.....	L.....	20 28 00	.....	.....	.....	.....	
		F.....	21 00 00?	.....	*50	.....	.....	
14	.....	L.....	21 56 30	.....	.....	.....	.....	P and S not recorded.
		L.....	22 07 00	.....	.....	.....	.....	
		L.....	22 19 36	.....	.....	.....	.....	
		M.....	.....	.....	*300?	.....	.....	
		F.....	22 29 42	.....	.....	.....	.....	
15	.....	eL.....	6 17 42	.....	.....	.....	.....	P and S not recorded; gradually increasing vibrations.
		eL.....	6 20 00	.....	.....	.....	.....	
		M.....	6 24 36	.....	*500	.....	.....	
		F.....	7 01 00	.....	.....	.....	.....	
16	.....	L.....	23 01 06	.....	.....	.....	.....	Trace faint from 22:15 to 22:50.
		L.....	23 09 42	.....	.....	.....	.....	
		eL.....	23 21 18	.....	.....	.....	.....	
		M.....	23 26 12	.....	*800	.....	.....	
		L.....	23 29 42	.....	.....	.....	.....	
17	.....	F.....	0 37 48	.....	.....	.....	.....	
18	.....	L.....	20 44 12	.....	.....	.....	.....	
		F.....	20 59 00	.....	*50	.....	.....	
19	.....	eL.....	11 31 24	.....	.....	.....	.....	P and S indistinct.
		iL.....	11 34 48	.....	.....	.....	.....	
		M.....	11 35 36	.....	*800	.....	.....	
		F.....	.....	.....	.....	.....	.....	Small micros.
24	.....	L.....	8 52 48	.....	.....	.....	.....	
		F.....	9 10 36	.....	*50	.....	.....	
24	.....	e.....	13 14 24	.....	.....	.....	.....	
		L.....	13 24 18	.....	.....	.....	.....	
		L.....	13 30 24	.....	.....	.....	.....	
		iL.....	13 41 12	.....	.....	.....	.....	
		M.....	13 43 12	.....	*2,800	.....	.....	Boom fairly steady from 14:38:30 to 14:50:00.
		eL.....	13 48 24	.....	.....	.....	.....	
		eL.....	14 21 36	.....	.....	.....	.....	
		eL.....	14 50 00	.....	.....	.....	.....	
		eL.....	14 53 12	.....	*400	.....	.....	
		F.....	15 38 18	.....	.....	.....	.....	
26	.....	L.....	15 29 54	.....	*50	.....	.....	
		F.....	15 36 42	.....	.....	.....	.....	

CANADA. *Dominion Meteorological Service, Victoria.*

1923.			*H. m. s.*	*Sec.*	*n*	*μ*	*Km.*
Feb. 5	.....	P.....	?3 44 09	5	.....	.....	.....
		L.....	3 50 29	12	.....	.....	.....
		M.....	3 56 49	12	2	.....	.....
		F.....	4 25 29	.....	.....	.....	.....
		P.....	?3 43 39	5	.....	.....	.....
		L.....	3 50 39	12	.....	.....	.....
		M.....	3 55 47	12	.....	2	.....
		F.....	4 24 54	.....	.....	.....	.....
5	.....	P.....	22 38 39	5	.....	.....	2,200
		S.....	22 42 19	10	.....	.....	.....
		L.....	22 47 29	15	.....	.....	.....
		M.....	22 53 19	15	4	.....	.....
		P.....	22 38 29	5	.....	.....	2,200
		S.....	22 42 09	10	.....	.....	.....
		L.....	22 47 19	15	.....	.....	.....
		M.....	22 56 44	15	.....	2	.....
5	.....	L.....	23 21 59	15	.....	.....	.....
		M.....	23 27 04	12	4	.....	.....
6	.....	F.....	0 00 49	.....	.....	.....	.....
5	.....	L.....	23 22 19	15	.....	.....	.....
		M.....	23 27 09	15	4	.....	.....
		F.....	23 47 59?	.....	.....	.....	.....
8	.....	P.....	0 40 28	5	.....	.....	2,760
		S.....	0 44 53	8	.....	.....	.....
		L.....	0 51 43	25	.....	.....	.....
		M.....	0 53 48	20	44	.....	.....
		F.....	1 11 53	.....	.....	.....	.....
		P.....	0 40 23	5	.....	.....	3,000
		S.....	0 45 03	8	.....	.....	.....
		L.....	0 51 43	20	.....	.....	.....
		M.....	0 54 03	15	.....	27	.....
		F.....	1 15 08	.....	.....	.....	.....
8	.....	P.....	8 06 52	5	.....	.....	1,910
		S.....	8 10 07	10	.....	.....	.....
		L.....	8 15 42	15	.....	.....	.....
		M.....	8 21 15	12	6	.....	.....
		F.....	8 53 27	.....	.....	.....	.....

* Trace amplitude.

CANADA. *Dominion Meteorological Service, Victoria*—Continued.

1923.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Feb. 8	.....	P.....	8 07 02	5	.....	.....	1,740	
		S.....	8 10 02	10	.....	.....	.....	
		L.....	8 14 52	15	.....	.....	.....	
		M.....	8 21 42	10	.....	4	.....	
		F.....	8 57 52	.....	.....	.....	.....	
8	.....	L.....	14 31 57	20	.....	.....	.....	
		M.....	14 36 52	10	7	.....	.....	
		F.....	14 47 17	.....	.....	.....	.....	
		L.....	14 31 27	20	.....	.....	.....	
		M.....	14 36 32	12	.....	10	.....	
		F.....	14 46 27	.....	.....	.....	.....	
9	.....	L.....	11 17 36	15	.....	.....	450	
		M.....	11 18 26	20	20	.....	.....	
		F.....	11 28 56	.....	.....	.....	.....	
		L.....	11 17 36	15	.....	.....	1,070?	
		M.....	11 19 31	10	.....	.....	.....	
		F.....	11 31 56	.....	.....	8	.....	
10	.....	L.....	?8 42 21	15	.....	.....	.....	
		M.....	8 45 45	15	2	.....	.....	
		F.....	8 50 07	.....	.....	.....	.....	
		L.....	8 42 50	20	.....	.....	.....	
		M.....	8 45 04	15	.....	1	.....	
		F.....	8 50 40	.....	.....	.....	.....	
11	.....	L.....	17 41 14	15	.....	.....	.....	
		M.....	17 42 24	15	2	.....	.....	
		F.....	17 57 24	.....	.....	.....	.....	
		L.....	17 41 26	15	.....	.....	.....	
		M.....	17 44 16	15	.....	1	.....	
		F.....	17 54 19	.....	.....	.....	.....	
11	.....	P.....	22 54 09	5	.....	.....	4,870	
		S.....	23 00 44	10	.....	.....	.....	
		L.....	23 08 14	15	.....	.....	.....	
		M.....	23 13 39	15	13	.....	.....	
		F.....	23 55 19	.....	.....	.....	.....	
		P.....	22 53 54	5	.....	.....	4,880	
		S.....	23 00 30	8	.....	.....	.....	
		L.....	23 09 04	15	.....	.....	.....	
		M.....	23 12 09	15	.....	6	.....	
		F.....	23 50 49	.....	.....	.....	.....	
12	.....	P.....	2 06 54	5	.....	.....	1,160	
		S.....	2 08 58	8	.....	.....	.....	
		L.....	2 13 13	12	.....	.....	.....	
		M.....	2 17 23	12	10	.....	.....	
		F.....	?3 12 37	.....	.....	.....	.....	
		P.....	2 06 54	5	.....	.....	1,100	
		S.....	2 08 52	8	.....	.....	.....	
		L.....	2 13 34	15	.....	.....	.....	
		M.....	2 17 46	25	.....	27	.....	
		F.....	3 36 34	.....	.....	.....	.....	
12	.....	P & L.	18 19 54	2	.....	.....	40	Felt in Victoria and Bellingham at 18:20, duration 1 second; not recorded at Seattle. Probably under Gulf of Georgia.
		M.....	18 19 58	2	4	.....	.....	
		F.....	18 21 27	.....	.....	.....	.....	
		P & L.	18 19 54	2	.....	.....	40	
		M.....	18 19 58	2	.....	4	.....	
		F.....	18 20 17	.....	.....	.....	.....	
			VERTICAL					
		P & L.	18 19 54	2	.....	.....	40	
		M.....	18 19 58	2	6	.....	.....	
		F.....	18 20 52	.....	.....	.....	.....	
16	.....	P.....	9 32 38	5	.....	.....	2,790	
		S.....	9 36 53	7	.....	.....	.....	
		L.....	9 41 04	35	.....	.....	.....	
		M.....	9 41 40	25	15	.....	.....	
		F.....	9 43 00	.....	.....	.....	.....	
		P.....	9 32 38	8	.....	.....	.....	
		S.....	9 36 53	8	.....	.....	2,760	
		L.....	9 40 40	35	.....	.....	.....	
		M.....	9 41 15	25	.....	12	.....	
		F.....	9 43 00	.....	.....	.....	.....	
18	.....	P.....	23 49 52	5	.....	.....	2,960	
		S.....	23 54 32	8	.....	.....	.....	
		L.....	0 04 50	20	.....	.....	.....	
		M.....	0 10 12	15	4	.....	.....	
		F.....	1 08 36	.....	.....	.....	.....	
		P.....	23 48 07	5	.....	.....	4,680?	
		S.....	23 54 32	11	.....	.....	.....	
19	.....	L.....	0 04 42	20	.....	.....	.....	
		M.....	0 12 02	15	.....	2	.....	
		F.....	1 05 39	.....	.....	.....	.....	
19	.....	P.....	6 43 54	6	.....	.....	.....	NS too indefinite to measure.
		L.....	7 04 22	30	.....	.....	.....	
		M.....	7 06 42	25	5	.....	.....	
		F.....	7 42 22	.....	.....	.....	.....	
20	.....	L.....	19 26 33	20	.....	.....	.....	
		M.....	19 27 13	15	4	.....	.....	
		F.....	19 40 36	.....	.....	.....	.....	

TABLE 3.—*Lake reports (instrumental)*—Continued.

CANADA. *Dominion Meteorological Service, Victoria*—Continued.

1923.			H. m. s.	Sec.	μ	μ	Km.	
Feb. 20	.....	L.....	19 26 14	20	.....	.....	.....	
		M.....	19 27 23	15	4	.....	.....	
		F.....	19 49 34	.....	.....	.....	.....	
21	.....	P.....	1 03 28	6	.....	.....	.....	
		S.....	1 10 18	10	.....	.....	5,150	
		L.....	1 22 08	20	.....	.....	.....	
		M.....	1 27 48	15	4	.....	.....	
		F.....	3 06 25	.....	.....	.....	.....	
		S.....	1 10 06	10	.....	.....	.....	
		M.....	1 26 20	12	2	.....	.....	
		F.....	2 08 43	.....	.....	.....	.....	
21	.....	P or S.	4 05 20	7	.....	.....	.....	
		L.....	4 09 01	25	.....	.....	.....	
		M.....	4 14 08	20	3	.....	.....	
		F.....	4 38 58	.....	.....	.....	.....	
		P or S.	4 05 23	7	.....	.....	.....	
		L.....	4 09 03	25	.....	.....	.....	
		M.....	4 13 13	20	3	.....	.....	
		F.....	4 38 58	.....	.....	.....	.....	
23	.....	P.....	6 15 14	5	.....	.....	730	
		S.....	6 16 34	7	.....	.....	.....	
		L.....	6 19 17	12	.....	.....	.....	
		M.....	6 19 27	10	12	.....	.....	
		F.....	7 40 19	.....	.....	.....	.....	
		P.....	6 15 11	5	.....	.....	760	
		S.....	6 16 34	7	.....	.....	.....	
		L.....	6 19 24	10	.....	.....	.....	
		M.....	6 19 34	10	.....	6	.....	
		F.....	7 17 24	.....	.....	.....	.....	
24	.....	P.....	7 42 52	7	.....	.....	4,700	West of Victoria.
		S.....	7 49 18	10	.....	.....	.....	
		L.....	7 58 33	20	.....	.....	.....	
		M.....	8 03 22	29	317	.....	.....	
		F.....	11 24 32	.....	.....	.....	.....	
		P.....	7 42 52	7	.....	.....	4,700	
		S.....	7 49 18	10	.....	.....	.....	
		L.....	7 58 57	17	.....	.....	.....	
		M.....	8 03 29	17	.....	178	.....	
		F.....	11 42 47	.....	.....	.....	.....	
27	.....	P.....	20 44 15	5	.....	.....	1,650	
		S.....	20 47 06	10	.....	.....	.....	
		L.....	20 48 45	25	.....	.....	.....	
		M.....	20 54 03	11	6	.....	.....	
		F.....	21 45 00	.....	.....	.....	.....	
		P.....	20 44 15	5	.....	.....	1,620	
		S.....	20 47 03	10	.....	.....	.....	
		L.....	20 48 45	30	.....	.....	.....	
		M.....	20 54 35	8	5	.....	.....	
		F.....	.....	.....	.....	.....	.....	Clock stopped.
Mar. 1	.....	P.....	8 32 29	8	.....	.....	2,080	No record on NS; clock stopped.
		S.....	8 35 59	12	.....	.....	.....	
		L.....	8 42 49	15	.....	.....	.....	
		M.....	8 51 54	15	14	.....	.....	
2	.....	P.....	17 03 33	7	.....	.....	5,050	Do.
		S.....	17 13 18	15	.....	.....	.....	
		L.....	17 21 45	20	.....	.....	.....	
		M.....	17 36 57	23	88	.....	.....	
		F.....	19 36 58	.....	.....	.....	.....	
4	.....	P.....	7 15 43	8	.....	.....	.....	
		L.....	7 29 02	15	.....	.....	.....	
		M.....	7 45 25	15	4	.....	.....	
		F.....	8 14 27	.....	.....	.....	.....	
		P.....	7 15 50	8	.....	.....	.....	
		L.....	7 28 57	11	.....	.....	.....	
		F.....	8 08 07	.....	.....	.....	.....	
11	.....	L.....	23 10 35	25	.....	.....	.....	
		M.....	23 12 10	15	22	.....	.....	
		F.....	23 20 35	.....	.....	.....	.....	
		L.....	23 09 20	20	.....	.....	.....	
		M.....	23 12 55	14	.....	27	.....	
		F.....	23 26 00	.....	.....	.....	.....	
13	.....	P.....	20 03 40	7	.....	.....	2,100	
		S.....	20 07 12	10	.....	.....	.....	
		L.....	20 11 50	20	.....	.....	.....	
		M.....	20 15 25	15	5	.....	.....	
		F.....	20 50 00	.....	.....	.....	.....	
		P.....	20 03 40	7	.....	.....	1,970	
		S.....	20 07 00	15	.....	.....	.....	
		L.....	20 11 20	20	.....	.....	.....	
		M.....	20 13 30	20	.....	5	.....	
		F.....	20 33 45	.....	.....	.....	.....	
14	.....	P.....	21 08 37	7	.....	.....	6,220	
		S.....	?21 16 25	20	.....	.....	.....	
		L.....	21 31 00	25	.....	.....	.....	
		M.....	21 31 48	20	7	.....	.....	
		F.....	?22 41 36	.....	.....	.....	.....	

CANADA. *Dominion Meteorological Service, Victoria*—Continued.

1923.			H. m. s.	Sec.	μ	μ	Km.
Mar. 14	.....	P.....	21 08 35	5	.....	.....	5,680
		S.....	21 15 54	10	.....	.....	.....
		L.....	21 24 45	35	.....	.....	.....
		M.....	21 25 12	30	.....	11	.....
		F.....	22 49 20	.....	.....	.....	.....
15	.....	P.....	6 02 55	5	.....	.....	.....
		L.....	6 22 45	20	.....	.....	.....
		M.....	6 30 33	17	8	.....	.....
		F.....	7 27 00	.....	.....	.....	.....
		P.....	6 02 57	5	.....	.....	.....
		L.....	6 25 05	20	.....	.....	.....
		M.....	6 30 11	20	.....	13	.....
		F.....	7 26 20	.....	.....	.....	.....
16	.....	P.....	22 15 16	7	.....	.....	10,220
		S.....	22 23 24	10	.....	.....	.....
		L.....	22 42 19	20	.....	.....	.....
		M.....	22 55 52	17	18	.....	.....
		F.....	1 02 57	.....	.....	.....	.....
		P.....	22 15 27	8	.....	.....	10,370
		S.....	22 26 42	10	.....	.....	.....
		L.....	22 42 12	30	.....	.....	.....
		M.....	22 42 46	18	.....	22	.....
		F.....	1 11 02	.....	.....	.....	.....
18	.....	P.....	20 36 55	7	.....	.....	.....
		L.....	20 39 40	15	.....	.....	.....
		M.....	20 42 26	12	5	.....	.....
		F.....	20 53 20	.....	.....	.....	.....
		P.....	20 36 55	7	.....	.....	.....
		L.....	20 39 40	20	.....	.....	.....
		M.....	20 42 25	10	.....	3	.....
		F.....	20 52 40	.....	.....	.....	.....
19	.....	P.....	11 30 28	10	.....	.....	.....
		L.....	11 39 12	40	.....	.....	.....
		M.....	11 47 14	16	6	.....	.....
		F.....	12 10 52	.....	.....	.....	.....
		P.....	11 30 20	8	.....	.....	.....
		L.....	11 38 22	40	.....	.....	.....
		M.....	11 48 15	16	.....	4	.....
		F.....	12 20 57	.....	.....	.....	.....
22	.....	L.....	18 49 43	10	.....	.....	.....
		M.....	18 50 23	12	5	.....	.....
		F.....	18 56 28	.....	.....	.....	.....
		P.....	18 47 23	7	.....	.....	.....
		L.....	18 49 43	10	.....	.....	.....
		M.....	18 51 03	7	5	.....	.....
		F.....	18 55 58	.....	.....	.....	.....
24	.....	P.....	12 53 26	5	.....	.....	.....
		S.....	13 03 58	12	.....	.....	.....
		L.....	13 20 58	42	.....	.....	.....
		M.....	13 32 26	23	201	.....	9,430
		F.....	15 58 26	.....	.....	.....	.....
		P.....	12 53 31	5	.....	.....	.....
		S.....	13 03 56	11	.....	.....	.....
		L.....	13 21 31	50	.....	.....	.....
		M.....	13 30 56	21	.....	191	9,290
		F.....	15 57 21	.....	.....	.....	.....
26	.....	P.....	14 02 47	8	.....	.....	.....
		L.....	14 03 49	10	.....	.....	.....
		M.....	14 04 39	10	1	.....	.....
		F.....	14 08 49	.....	.....	.....	.....
		P.....	14 02 46	10	.....	.....	.....
		L.....	14 02 54	12	.....	.....	.....
		M.....	14 04 14	10	.....	1	.....
		F.....	14 10 09	.....	.....	.....	.....
26	.....	L.....	15 05 24	20	.....	.....	.....
		M.....	15 07 14	25	5	.....	.....
		F.....	15 41 34	.....	.....	.....	.....
		L.....	15 19 29	25	.....	.....	.....
		F.....	15 41 29?	.....	.....	.....	.....
28	.....	L.....	5 20 01	25	.....	.....	.....
		M.....	5 22 59	20	2	.....	.....
		F.....	5 47 16	.....	.....	.....	.....
		P.....	5 02 01	10	.....	.....	.....
		L.....	5 13 36	40	.....	.....	.....
		M.....	5 14 21	30	.....	2	.....
28	.....	L.....	22 15 14	15	.....	.....	.....
		M.....	22 15 47	15	5	.....	.....
		F.....	22 25 57	.....	.....	.....	.....
		L.....	22 15 34	15	.....	.....	.....
		M.....	22 16 56	10	.....	3	.....
		F.....	22 26 42	.....	.....	.....	.....

Chart I. Tracks of Centers of Anticyclones, April, 1923. (Inset) Departure of Monthly Mean Pressure from Normal.
(Plotted by Wilfred P. Day.)

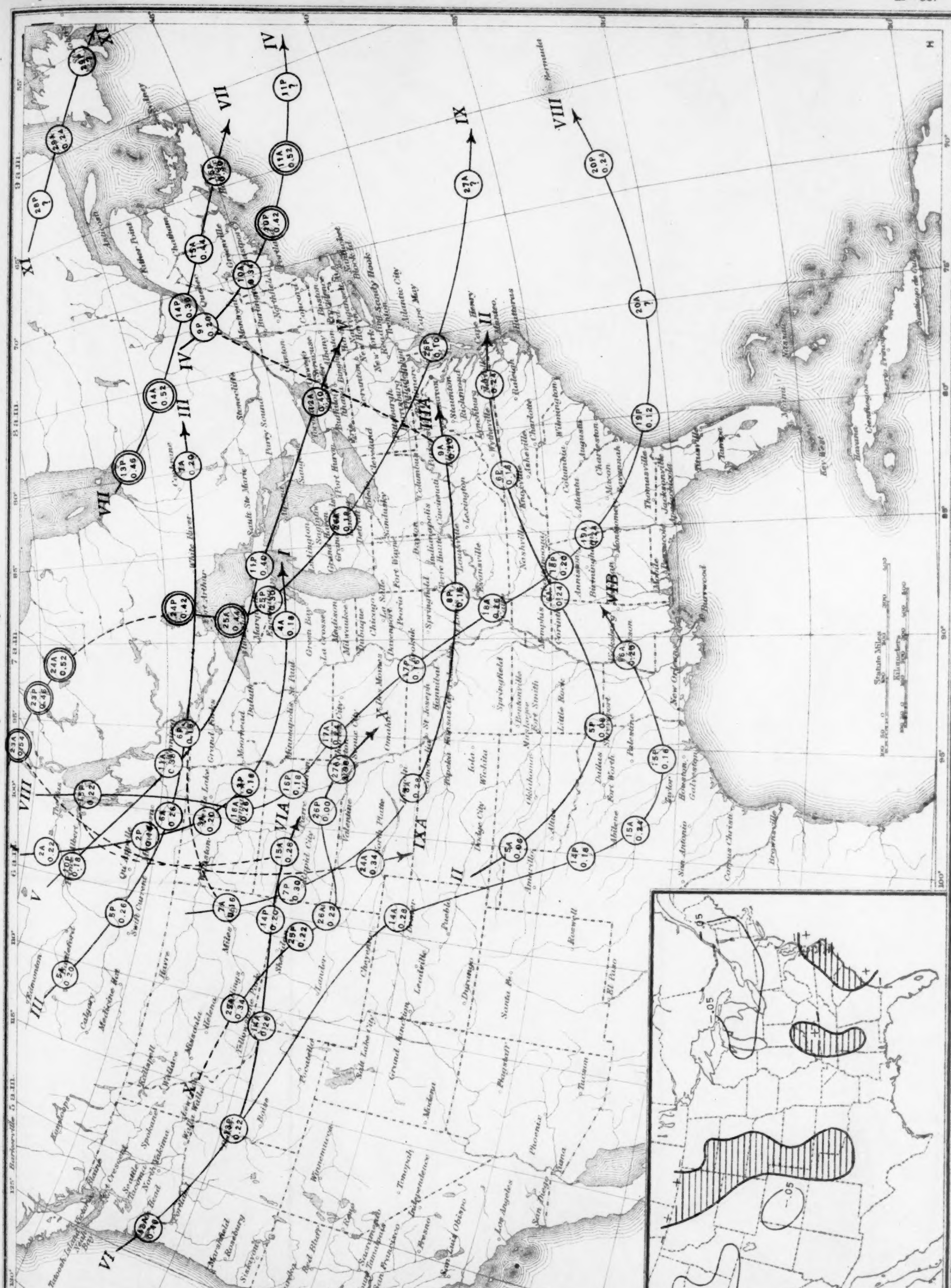


Chart I. Tracks of Centers of Anticyclones, April, 1923. (Inset) Departure of Monthly Mean Pressure from Normal.
(Plotted by Wilfred P. Day.)

Chart II. Tracks of Centers of Cyclones, April, 1923. (Inset) Change in Mean Pressure from Preceding Month.

(Plotted by Wilfred P. Day.)

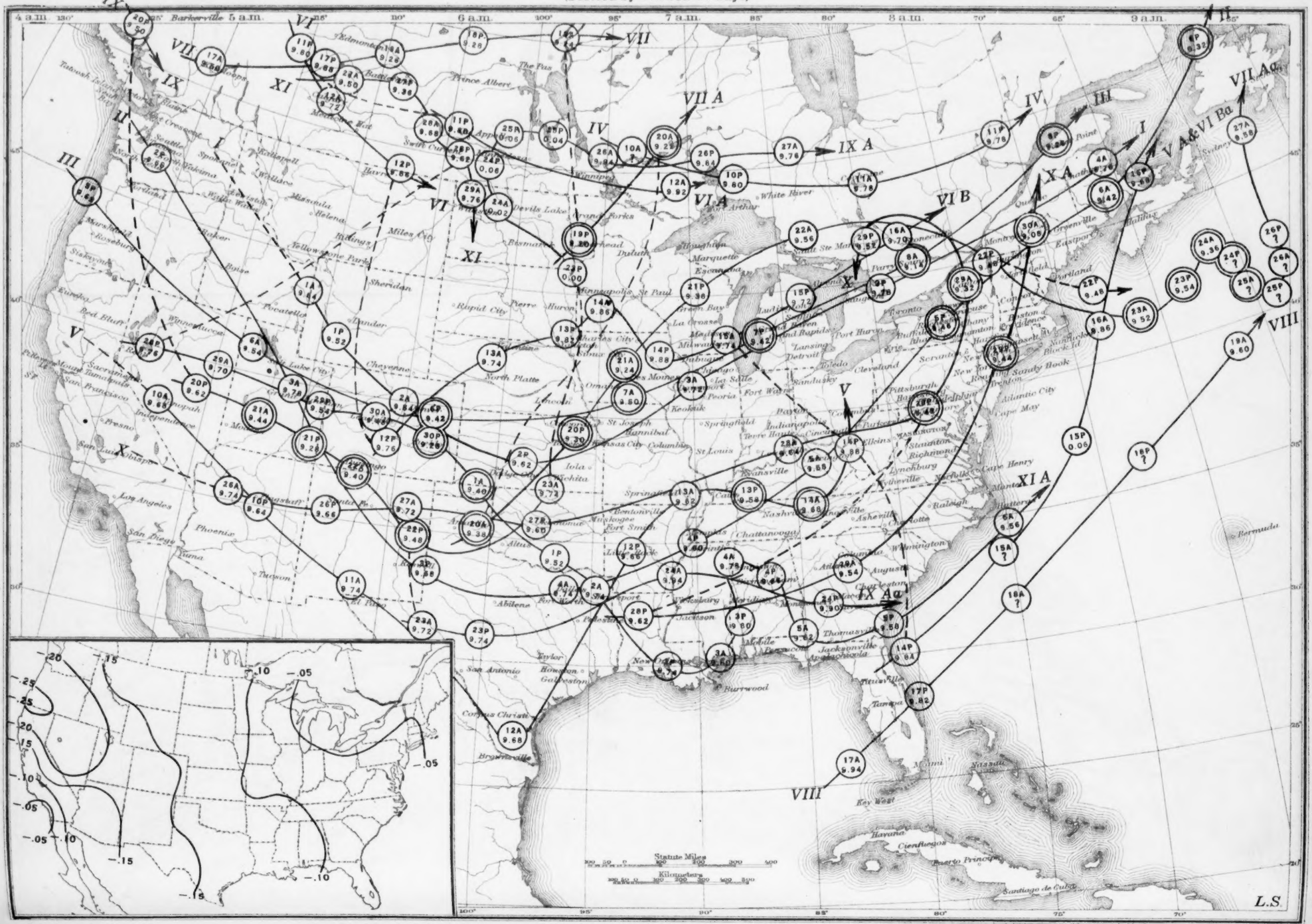


Chart III. Departure (°F.) of the Mean Temperature from the Normal, April, 1923.

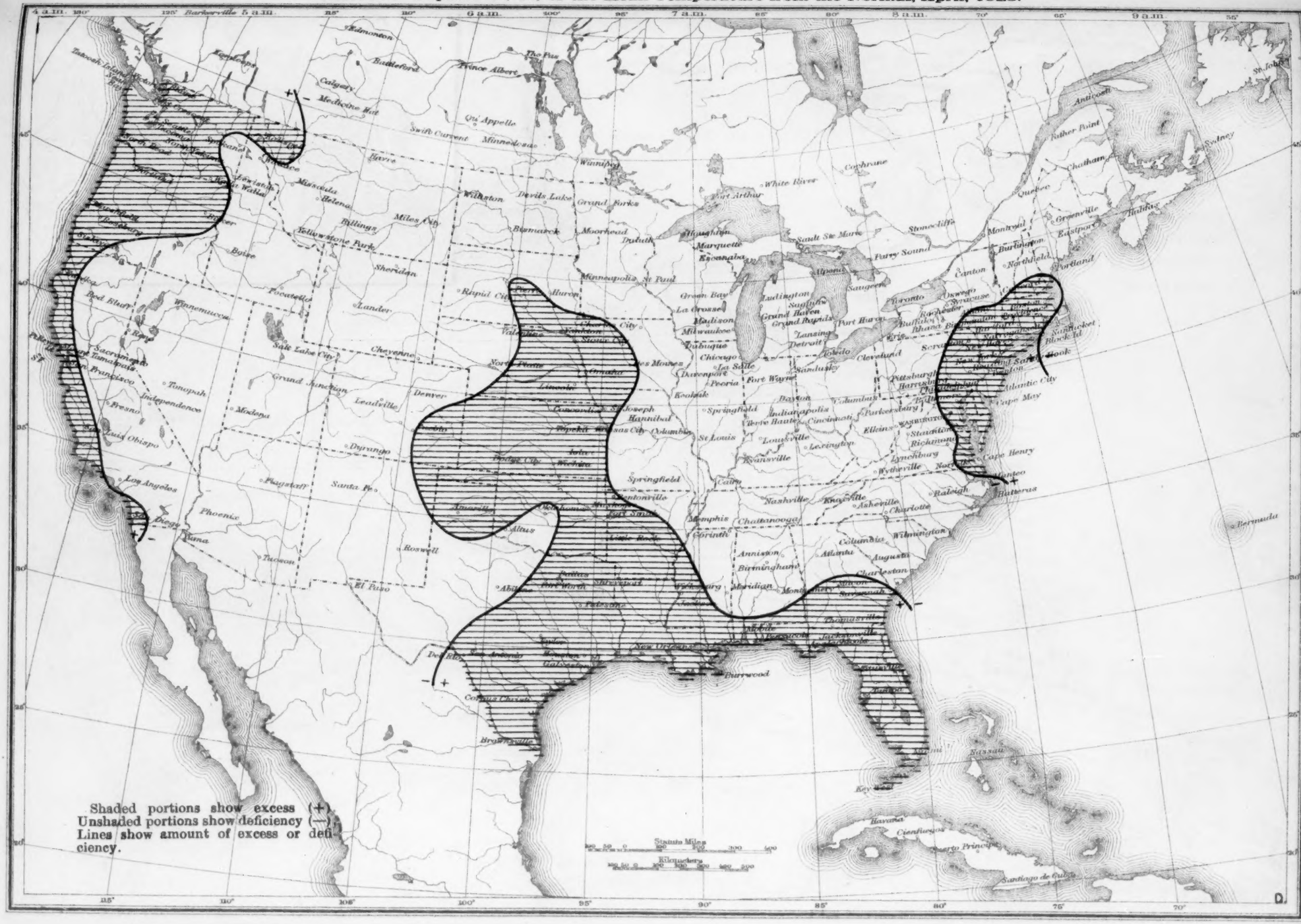

Shaded portions show excess (+).
Unshaded portions show deficiency (—).
Lines show amount of excess or deficiency.
Statute Miles
Kilometers

Chart IV. Total Precipitation, Inches, April, 1923. (Inset) Departure of Precipitation from Normal.

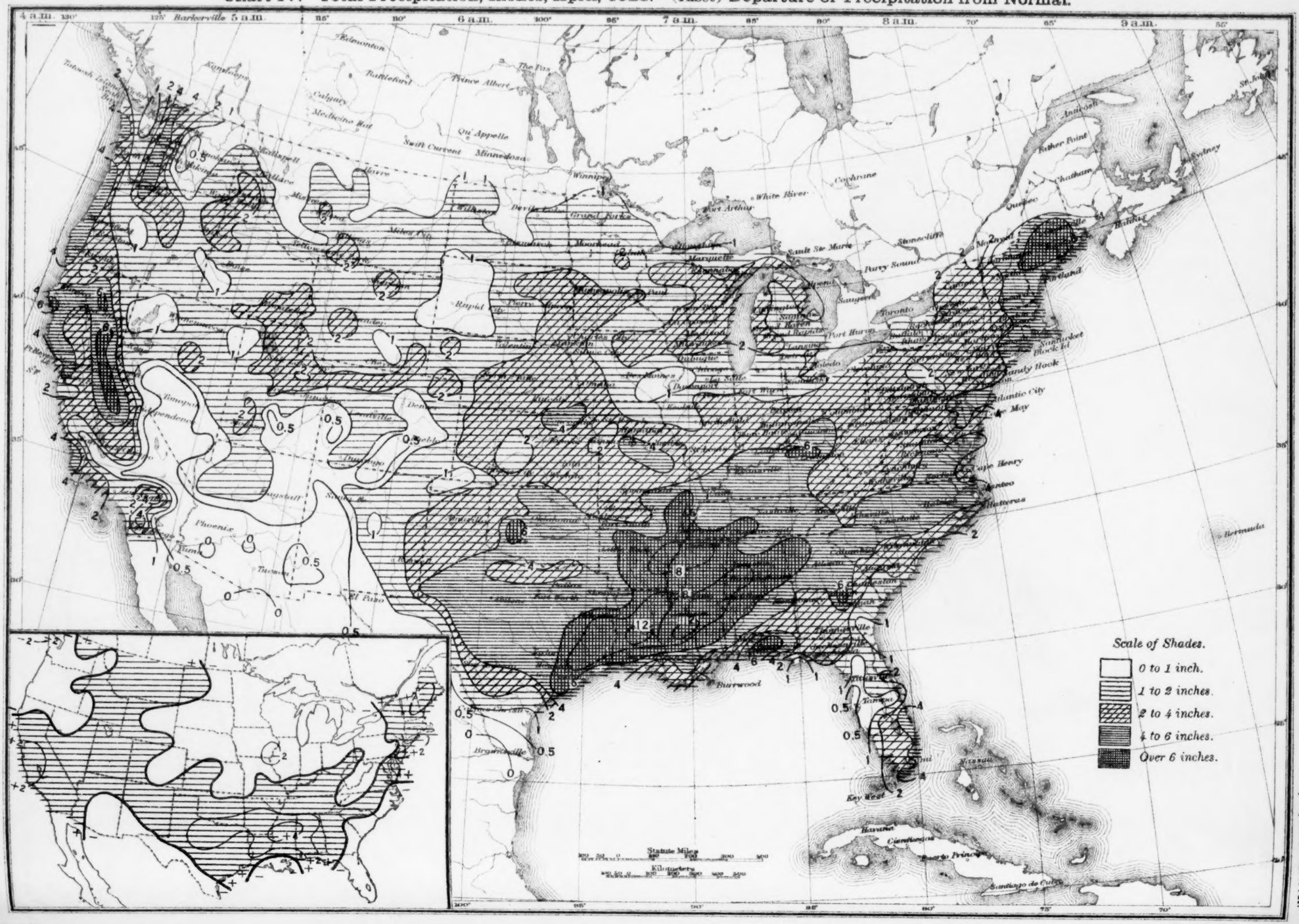


Chart V. Percentage of Clear Sky between Sunrise and Sunset, April, 1923.

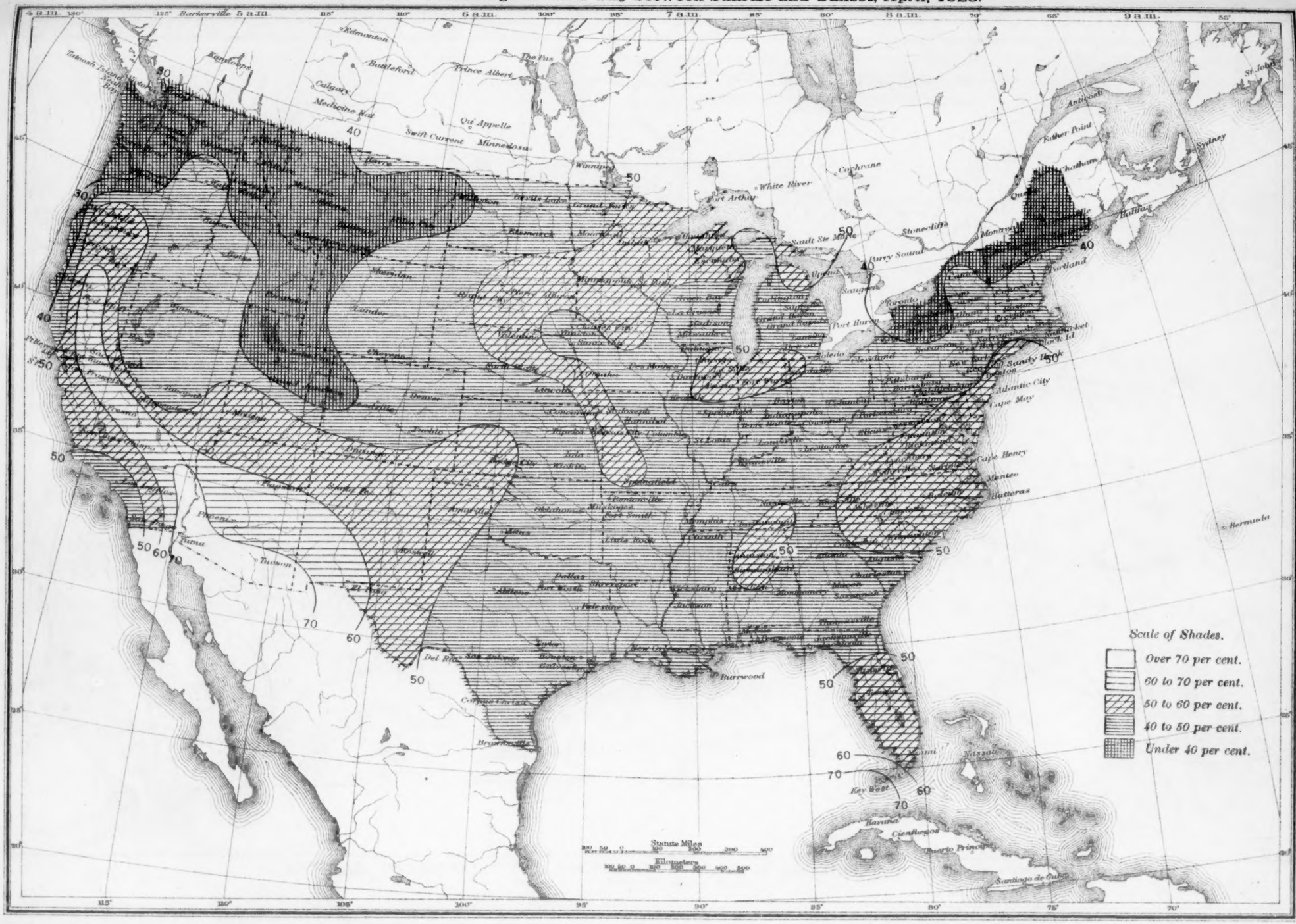


Chart VI. Isobars at Sea-level and Isotherms at Surface; Prevailing Winds, April, 1923.

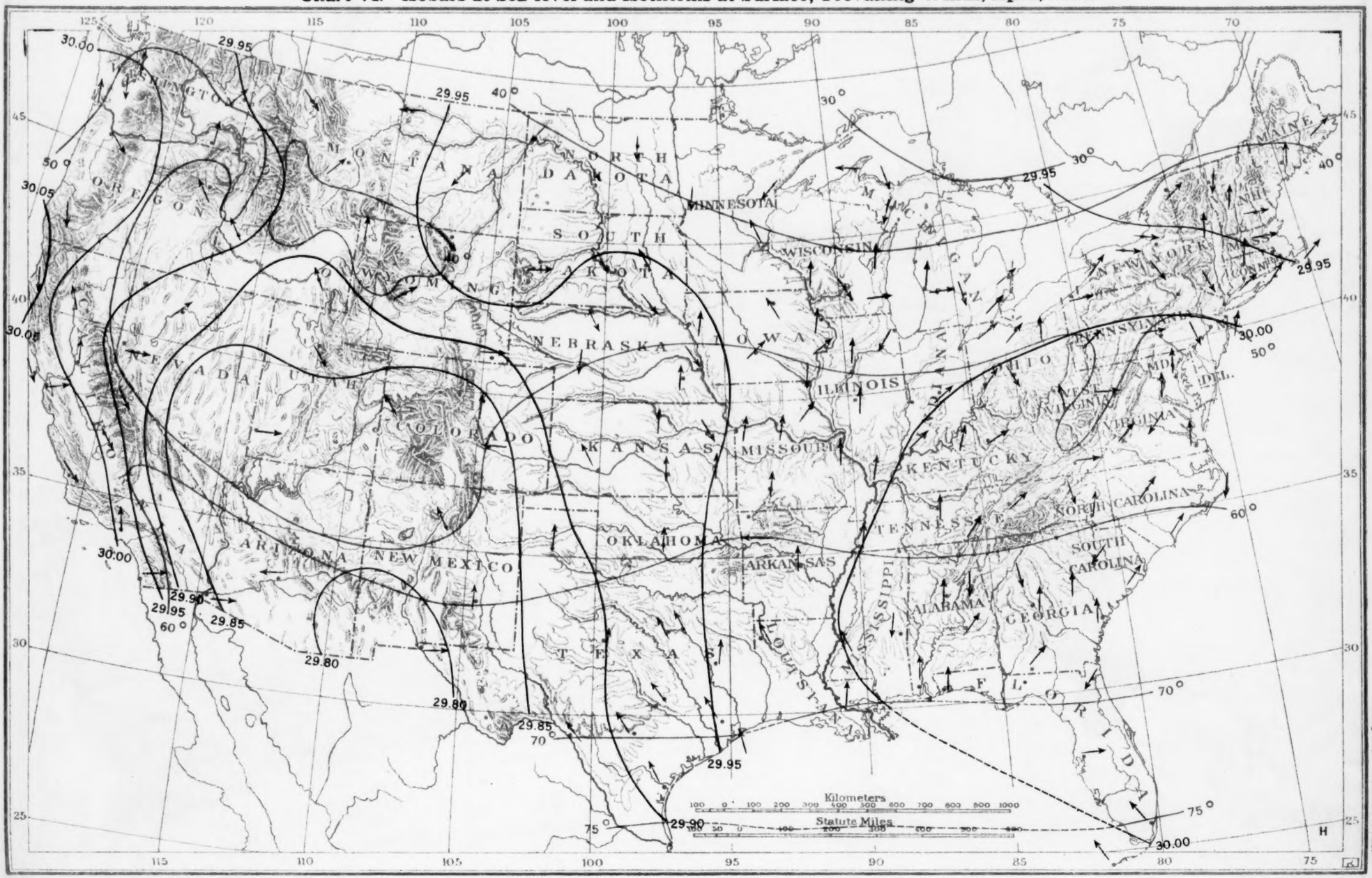


Chart VII. Total Snowfall, Inches, April, 1923.

Chart VIII. Weather Map of North Atlantic Ocean, April 8, 1923

Chart VIII. Weather Map of North Atlantic Ocean, April 9, 1923.
(Plotted by F. A. Young.)

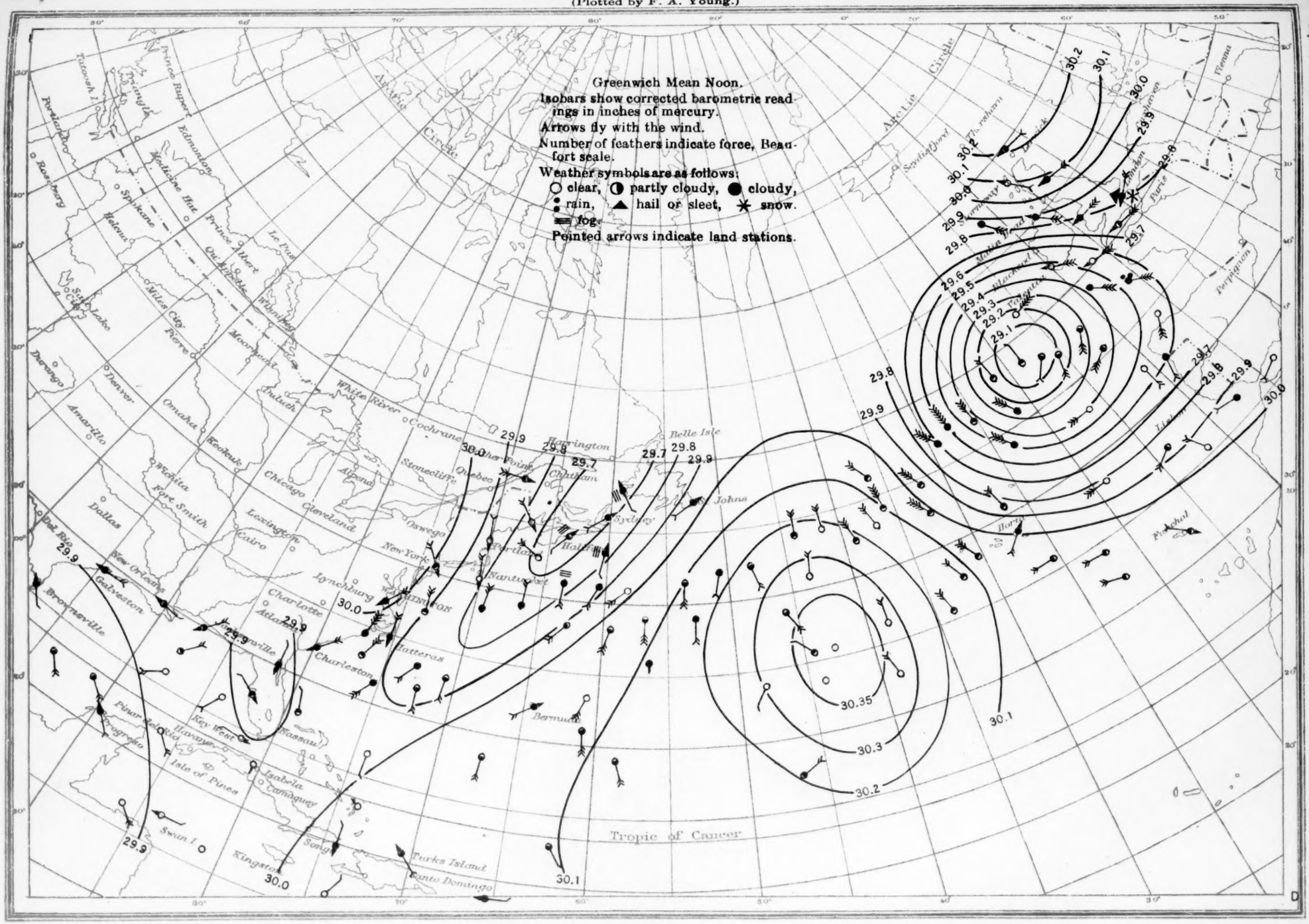
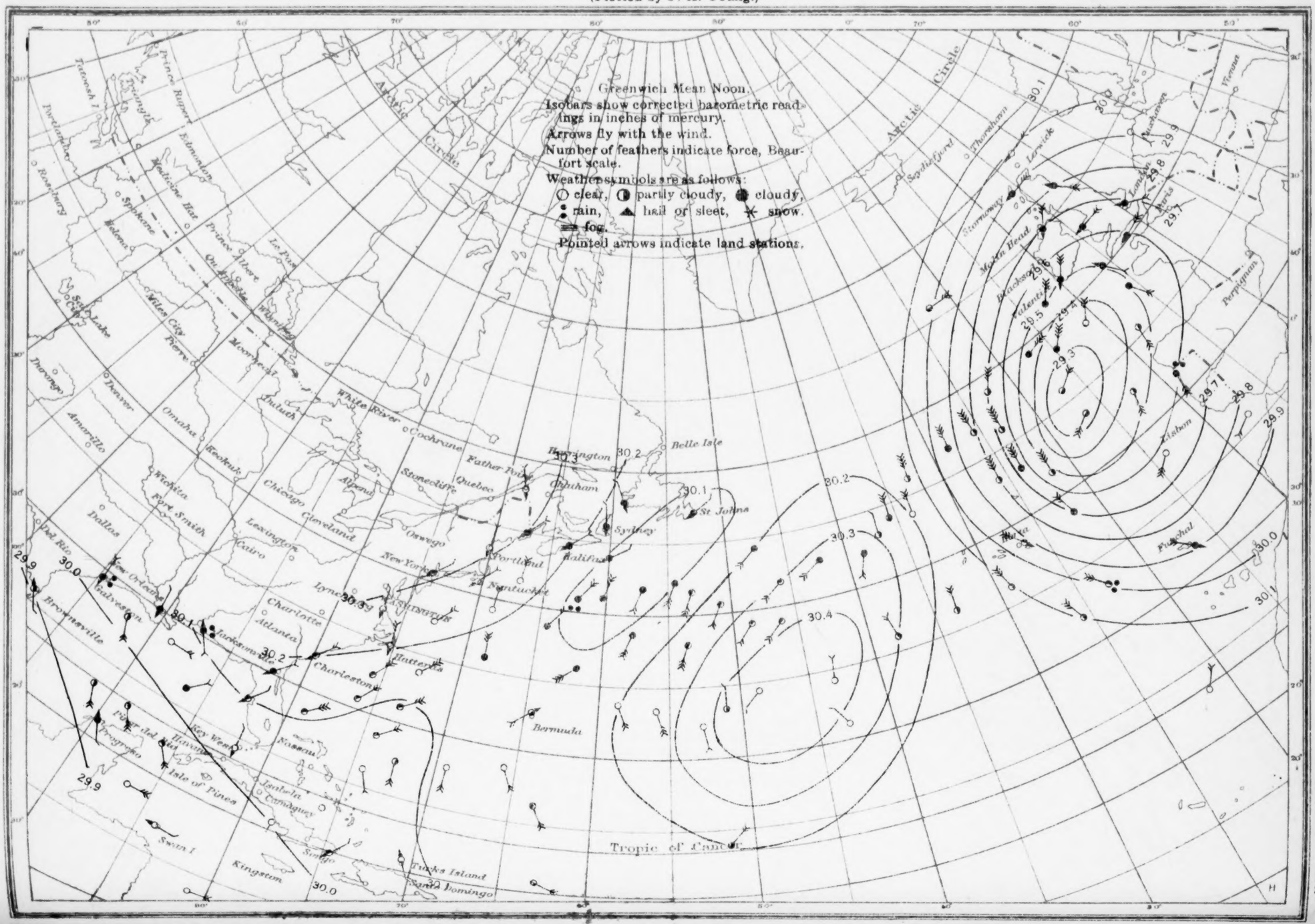


Chart IX. Weather Map of North Atlantic Ocean, April 10, 1923.

(Plotted by F. A. Young.)